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## **The Big Three in Semiconductors—Intel, NVIDIA and AMD By Huanyu Liu**

### **Introduction**

Intel, NVIDIA and AMD are three of the world's largest manufacturers of computer chips and have recently branched out into other areas such as specialized gaming chips, artificial Intelligence, cloud computing, etc. These companies are pursuing many of the same objectives but each has its own unique strategy; it remains to be seen which approach will result in the most rapid technological advancement and profitability.

The competitive relationship between these three companies can be summarized as follows: Competition: NVIDIA and Intel compete directly in the datacenter and Artificial Intelligence (AI) space, especially in deep learning training and inference. Nvidia's Graphics Processing Units (GPUs) are a major competitor with their strengths in parallel computing. Collaboration: although they compete fiercely in some areas, these companies may also collaborate. For example, some vendors may use Intel's processors and NVIDIA's GPUs to build AI solutions. As another example, NVIDIA is collaborating with Intel to provide attestation services for Nvidia H100 GPUs. Attestation ensures the safety and security of these GPU chips. Different markets: they also specialize in different markets and areas. In addition to the AI space, Intel and AMD compete in personal computers, servers, and other areas. In addition to the competitive relationship between Intel, NVIDIA, and AMD, these companies face others as competitors in the AI space, especially in the areas of AI hardware, AI solutions, and cloud computing. Here are some other important competitors.

### **Competitors**

Google is a tech giant with a strong presence in the AI space. Google's Tensor Processing Units (TPUs) are AI chips specifically designed to accelerate deep learning tasks. Google has also developed TensorFlow, a widely used open-source deep learning framework. (Deep learning means that a computer model learns from data; for example, facial recognition software.) Google also has leading positions in cloud computing, natural language processing, and computer vision.

Microsoft is also a global technology company with its own AI research and development division. Microsoft has the Azure cloud platform in the cloud computing sector, which offers a wide range of AI solutions and tools. In addition, Microsoft is also developing deep learning frameworks such as Microsoft Cognitive Toolkit (CNTK).

Amazon has Amazon Web Services (AWS) in the clouds, which provides powerful AI services and solutions such as Amazon SageMaker, which is a machine-learning service. Amazon has also developed its own AI technologies in natural language processing and computer vision.

Apple's focus in AI is primarily on the integration of AI applications such as Siri (voice assistant) and Core ML (machine learning framework for iOS devices). Apple has also invested in AI chip design to improve the AI performance of its mobile devices.

Huawei is a Chinese tech company that has also demonstrated strong R&D in AI. Huawei has invested and innovated heavily in AI chips (e.g., the Ascend series) and cloud services in an effort to expand its AI solutions globally.

Competition between these companies is driving the development of AI technology and fostering more innovation and collaboration. It is worth noting that due to the rapid changes in the technology industry, new competitors may have emerged or the position and competitive relationship between the aforementioned companies may have changed.

### **Gaming Hardware and Technology**

Intel, NVIDIA and AMD all play important roles in the gaming space, especially in providing gaming hardware and technology. NVIDIA is known for its powerful graphics processing units (GPUs) that excel in the gaming space. NVIDIA's GeForce family of GPUs is widely used in gaming PCs and gaming laptops, providing superior graphics performance and gaming experience. NVIDIA has also introduced many innovations in the gaming space, such as real-time ray tracing (a technique for producing 3D images) (Ray) and DLSS (Deep Learning Super Sampling Technology), which improve game quality and performance.

AMD also has a presence in the gaming space. AMD's Radeon family of GPUs is used in a wide range of gaming PCs and gaming consoles (e.g., PlayStation and Xbox). AMD's GPUs typically excel in price/performance ratio, which makes them attractive to many gamers. AMD is also continually adding new features to its Radeon software suite to improve gaming performance and experience.

While Intel does not have the market share in the gaming space that NVIDIA and AMD do, it is still a significant competitor. Intel's integrated graphics cards perform well in some light games and general applications, and they can provide playable performance in some lightweight gaming scenarios. However, Intel has been working hard to improve the performance of its graphics cards and plans to launch discrete graphics cards designed specifically for gaming to gain a larger market share in the gaming space.

The competition between these three companies in the gaming space has pushed gaming hardware technology forward, with gamers benefiting from ever-increasing graphics performance and gaming experiences. The gaming industry is a highly dynamic sector and these companies are striving to innovate and meet the growing demands of gamers. As a result, the future is likely to see more advanced technology and product launches to further enhance the gaming experience.

### **Performance of INTEL, NVIDIA and AMD**

Intel is a large American technology company known for making computer chips. They supply microprocessors for PCs and have been a major player in the industry. They compete with

AMD in PC chips and ARM in mobile devices such as modems. Intel has also faced antitrust disputes and is working to reduce its carbon emissions<sup>1</sup>.

Intel has a strong history of innovation and dominates the data-centric market. The company's main revenue comes from selling its products to manufacturers. Despite facing competition and some challenges, Intel remains a prominent player in the tech industry.

Intel's strategy is to provide top semiconductors for a data-centric world. They focus on growth, execution, capital deployment and culture. Targeting a \$300 billion market by 2024, their main areas are data-centric and PC-centric businesses. They lead in AI, 5G (5<sup>th</sup> generation mobile network), and the Intelligent edge. They have six technology pillars, allocate capital wisely and bet on memory, autonomous driving and 5G. Transforming their culture is a priority<sup>2</sup>.

The intelligent edge is a concept in computing and networking that refers to data processing and analysis taking place at the edge of the network or close to the source of the data, rather than sending it all to a centralized cloud server. It achieves the benefits of reduced latency (i.e., reduced delay in network communication), optimized bandwidth, enhanced security and support for offline operations by performing some of the processing on local devices, sensors or edge servers. Smart Edge is part of Edge Computing and is designed to optimize the performance and efficiency of IoT (Internet of Things) and data-driven applications.

Intel has restructured its graphics chips business into two parts: one for discrete GPUs and another for high-performance computing. A discrete GPU has its own memory distinct from the CPU, which improves performance but requires more power. This change aims to compete better with rivals Nvidia and AMD. Despite facing challenges, Intel sees graphics and accelerated computing as crucial for growth<sup>3</sup>.

Intel reported a significant drop in earnings and revenue for the first quarter of 2023<sup>4</sup>, but it performed slightly better than expected. The CEO's turnaround plan aims to compete with other chip manufacturers by 2026. The PC chip business is struggling, but there is growth in the self-driving car sector. Intel is cutting costs and improving gross margins to save money.

In Q1 2023, Intel reported a significant drop in revenue across all key businesses, with losses in client and data center segments. The net loss was \$2.8 billion. However, the CEO sees it as steady progress amid transformation efforts. Mobileye (the division responsible for “autonomous vehicles”) was the only segment with growth. For Q2 2023, Intel expects similar results with revenue of \$11.5 to \$12.5 billion.<sup>5</sup>

Nvidia is an American technology company famous for designing powerful graphics cards used in gaming, AI, and other applications. They also provide software for data science and high-performance computing. The company was founded in 1993 and has become a major player

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<sup>1</sup> <https://en.wikipedia.org/wiki/Intel>

<sup>2</sup> <https://www.intc.com/strategic-priorities>

<sup>3</sup> <https://qz.com/Intel-split-graphics-unit-nvidia-amd-dgpu-competition-1849922166>

<sup>4</sup> <https://www.fudzilla.com/news/56798-Intel-reports-its-q1-2023-financial-results>

<sup>5</sup> <https://www.fudzilla.com/news/56798-Intel-reports-its-q1-2023-financial-results>.

in the tech industry<sup>6</sup>.

NVIDIA and Intel are introducing new products with AI technologies<sup>7</sup>. NVIDIA has an AI-powered supercomputer platform for tech enterprises and an advertising service to reduce costs. They also offer AI for gaming experiences. Intel's upcoming CPUs will have an integrated AI engine and improved power management. Both companies use AI to stay competitive and meet growing demand for AI tasks.

Nvidia's revenue forecast surged, driven by the growing use of artificial Intelligence<sup>8</sup>. The demand for AI chips is increasing, reshaping the tech sector. Nvidia's AI chips are faster and more efficient than traditional CPUs for AI tasks, making them highly valuable. The strong guidance reflects the rising importance of AI in the tech industry.

Nvidia is predicted to have over 90% of the AI chip market share<sup>9</sup>, with AMD in second place. An analysis showed Nvidia's AI chips are about 80% faster than AMD's. Nvidia's superior speed and ecosystem give it an advantage in AI performance. Both companies have released new AI chips this year. Nvidia's market dominance is likened to Intel's position against AMD in the past.

Nvidia's stock surged to almost \$1 trillion in market cap after a strong outlook<sup>10</sup>. The demand for its GPUs in AI applications is driving sales growth. GPUs are becoming more important than CPUs for AI tasks. Nvidia's high-end GPUs are favored for AI applications due to proprietary software. The company remains a leader in AI chips despite competition.

AMD (Advanced Micro Devices) is an American semiconductor producer based in California. The company was founded in 1969 by Jerry Sanders and other computer professionals. Originally the company focused on memory chips for computers. Later it began to compete with industry leader Intel in the microprocessor market. Due to the success of its Athlon and Opteron processors, the company experienced rapid growth in the 2000's. By the 2010's, its Ryzen processors helped it keep up with Intel. AMD's microprocessors are widely used in personal computers, servers and gaming consoles. By 2009, the company had gone "fabless" which means designing microprocessors but outsourcing the actual production to other companies. Currently AMD has achieved a market capitalization of just under \$200 billion, making it one of the larger companies in this area.

AMD is challenging Nvidia's AI market dominance with its new AI chip, the AMD Instinct MI300X. This chip is a strong competitor to Nvidia, the current leader in the AI chip market. AMD aims to tap into the growing AI accelerator market, which is expected to reach

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<sup>6</sup><https://en.wikipedia.org/wiki/Nvidia#:~:text=Nvidia%20is%20a%20dominant%20supplier.scientific%20research%2C%20and%20manufacturing%20design.>

<sup>7</sup> <https://www.spiceworks.com/tech/artificial-Intelligence/news/nvidia-and-Intel-to-leverage-ai-in-latest-offerings/>

<sup>8</sup> <https://apnews.com/article/nvidia-stock-artificial-Intelligence-earnings-f6b9df3a4cafe1a4ee041cc736b97a89>

<sup>9</sup><https://www.marketwatch.com/story/nvidia-should-have-at-least-90-of-ai-chip-market-with-amd-on-its-heels-13d00bfff#:~:text=Nvidia%20Corp.,in%20servers%20a%20decade%20ago.>

<sup>10</sup><https://www.visualcapitalist.com/nvidia-joins-the-trillion-dollar-club/#:~:text=Chipmaker%20Nvidia%20is%20now%20worth,Apple%2C%20Amazon%2C%20and%20Microsoft.>

\$150 billion by 2027. (An AI accelerator is designed to optimize the performance of an AI system.) The MI300X is designed for generative AI (a form of machine learning that can produce text, videos, graphics, etc.) and is likely to interest cloud providers like Amazon and Microsoft. AMD aims to challenge Nvidia's leading position in AI chips. Nvidia has experienced strong revenue growth with its AI chips, contributing to its trillion-dollar valuation. The MI300X is designed for large language models and offers more memory capacity than Nvidia's H100. AMD also introduced an Infinity Architecture that combines eight MI300X accelerators in one system.

AMD presented its AI roadmap, featuring two key products: the MI300A APU accelerator and the MI300X GPU. The MI300X is designed for large language models in generative AI and is claimed to be the fastest GPU in this field<sup>11</sup>. AMD aims to compete with Nvidia's GPUs and is focused on providing a full range of AI hardware. The company is also working on developer education and collaborating with the Hugging Face AI community. Hugging Face is an open source community which creates tools that enable users to implement machine learning models.

### Financial Performance

The past year (July 2022 – July 2023) saw strong performances by NVIDIA and AMD with a very poor performance by INTEL. The mean returns, variances and standard deviations (on an annualized basis) are shown in the following table:

	INTEL	NVIDIA	AMD
<b>Mean</b>	-0.031991162	1.136232273	0.376255541
<b>Variance</b>	0.164216989	0.336329448	0.283148446
<b>Standard Deviation</b>	0.405236954	0.579939176	0.532116947

Source: finance.yahoo.com

The statistics show that on an annualized basis, Intel lost over 3% while AMD made nearly 38% and Nvidia earned returns of about 114%. The risk of Intel stock, as measured by the standard deviation of its returns, was the lowest of the three companies at about 40.5%, but this was only somewhat lower than the 58% of NVIDIA and 53% of AMD.

The poor performance of Intel can be at least partially attributed to the company's recent move to restructure its development process based on technology modules. The goal is to accelerate the development of new technology and create the next generation of computer chips. This is expected to increase the competitive position of the company, attract new external customers and cut costs. In the short run, these innovations will likely be very expensive and new revenue sources will not become available right away, so that profits are likely to suffer over this period. In the long run, though, these investments have the potential to greatly improve Intel's competitive position and profitability.

<sup>11</sup> <https://www.datacenterfrontier.com/machine-learning/article/33006628/amd-outlines-their-ai-roadmap>



NVIDIA and AMD are experiencing rapid growth due to their innovations such as developing the latest graphics chips and their entry into the AI market.

## **Applications**

There are many potential applications of computer chip technology, including:

- artificial Intelligence (AI)
- cloud computing
- graphics

## **AI**

The rise of AI, particularly generative AI tools like ChatGPT, has driven significant growth in the tech industry post-pandemic. Generative AI can be used for:

- image generation and enhancement
- text generation and summation
- music and audio generation
- video generation and prediction
- drug discovery and molecular design
- virtual avatars and characters
- style transfer and image-to-image translations
- data augmentation
- simulation and training
- anomaly detection

AI hardware manufacturers, such as NVIDIA, AMD, TSM, and Micron, have seen soaring stock prices due to the AI surge. Software companies like Meta (formerly Facebook), Microsoft, and Alphabet (Google's parent company) are also benefiting from the AI boom. AI is reshaping the tech sector and becoming a dominant force in driving innovation and market growth.

WPP, the world's largest advertising agency, has teamed up with Nvidia to use artificial Intelligence (AI) for creating ads. This AI-powered platform allows WPP's creative teams to efficiently produce advertising campaigns on a large scale. It can customize ads for different countries, cities, and digital channels, making them more engaging. The technology enhances productivity and enables brands to deploy realistic and immersive content like never before. However, there are concerns about AI potentially impacting jobs in the advertising and media industries. Nonetheless, the partnership aims to revolutionize content creation for commercial use<sup>12</sup>.

## **Cloud Computing**

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<sup>12</sup> <https://edition.cnn.com/2023/05/29/tech/nvidia-wpp-ai-advertising/index.html>

Simply put, cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and Intelligence—over the internet (“the cloud”) to offer faster innovation, flexible resources, and economies of scale. Intel provides a trusted foundation for organizations' cloud strategies, supporting private, public and hybrid clouds, and the Intelligent edge. They offer an open-source approach, ensuring compatibility with existing systems. Intel helps with AI implementation, cost optimization, and microservices migration through a sophisticated toolset. They collaborate with major cloud providers and offer a variety of products for better cloud performance<sup>13</sup>.

GeForce Now is a cloud gaming service by Nvidia. It lets users play video games remotely through streaming. It offers a library of games or allows users to play their own purchased games. It supports various devices and uses Nvidia graphics cards for high-quality streaming<sup>14</sup>.

A study by CockroachDB<sup>15</sup> showed that AMD's processors outperformed Intel's in cloud performance on AWS (Amazon Web Services), Azure, and Google Cloud. AMD was both the overall performance and price-for-performance leader. GCP's (Google Cloud Platform) AMD-based instance performed the best, followed by GCP's Intel-based and AWS's Intel-based instances. The study highlighted the importance of considering storage and data transfer costs when choosing a cloud provider.

AMD's processors are gaining ground in the datacenter market, with over 130 cloud instances launched by major providers like Amazon, Microsoft, and Google<sup>16</sup>. Their server market share reached 16% last year. AMD's strong performance resulted in a 49% revenue increase in Q4. The acquisition of Xilinx was approved in China, adding to their chip design capabilities. AMD's multi-core performance is superior to Intel's, making it popular for cloud-based applications. Cloud vendors are investing more in AMD-powered instances due to their performance and power efficiency.

## Graphics Chips

Nvidia's A100 GPU has become a critical tool for the AI industry and is being used by companies like Microsoft and Google to power their AI applications. As AI technology continues to advance, the need for powerful GPUs like the A100 is increasing, leading to a surge in demand and driving Nvidia's earnings growth. Other companies are also developing AI-specific chips, but Nvidia remains a dominant player in the AI hardware market.

## Political Considerations

The Biden administration is considering an AI chip ban to restrict the export of

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<sup>13</sup><https://www.intc.com/news-events/press-releases/detail/1543/Intel-announces-new-cloud-to-edge-technologies-to-solve>

<sup>14</sup> [https://en.wikipedia.org/wiki/GeForce\\_Now](https://en.wikipedia.org/wiki/GeForce_Now)

<sup>15</sup> <https://www.cockroachlabs.com/blog/2022-cloud-report/>

<sup>16</sup> <https://www.thestack.technology/amd-cloud-wins/>

technology with military applications to China<sup>17</sup>. This could severely impact companies like Nvidia and AMD. The ban may affect their sales and trading, and shares of these companies fell after the news. The new restrictions would require a special U.S. export license for certain AI chips. This move could have a significant impact on the success of Nvidia and AMD, which have seen substantial growth in 2023.

## **The Risks**

Intel, NVIDIA, and AMD all face potential risks such as intense competition, pressure for technological advances, fluctuations in market demand, risk of supply chain disruptions, regulatory and legal issues, and cybersecurity threats. In addition, specific events such as Intel's technology node transition and NVIDIA's acquisition of Arm (a chip producer) could have a significant impact on their future plans. Investors and stakeholders need to pay close attention to these risks in order to make informed investment and business decisions.

Cloud Computing, Artificial Intelligence and Graphics Chips are three interrelated and rapidly growing demand segments in the technology industry. Cloud computing is experiencing exponential growth in demand for its services owing to its flexibility and cost-effectiveness. Artificial Intelligence is widely used in various industries through advantages such as automation and improved decision making. Graphics chips also continue to grow in demand in gaming and other parallel processing areas. Intel, NVIDIA, and AMD all play an important role in cloud computing, artificial intelligence, and graphics applications, providing the appropriate hardware and solutions. Demand in these markets is expected to continue to grow as digital transformation and data-driven decision-making accelerate, and all three companies will continue to drive technology, bringing new innovations and opportunities to a wide range of industries.

## **Conclusions**

Intel is currently switching its focus from the Next Unit of Computing business, which focuses on mini PC's, a type of core computer that requires the addition of a monitor, keyboard and mouse. Intel is pursuing consumer GPU's (graphics processing unit), data center GPU's, consumer AI chips, etc. Currently Intel's market share of these products is quite small compared with NVIDIA and AMD. Increasing its market share in these areas could be potentially very lucrative for Intel, but is likely to take a significant amount of time. Intel is also changing the way that it packages together its "chiplets." (A chiplet is a very small chip that is used in conjunction with other chiplets to perform highly complex tasks more efficiently than traditional chips.) Currently Intel is the leader of 3D packaging capabilities. Intel is also expanding its capabilities as a semiconductor foundry (i.e., it produces semiconductors for other companies) which manufactures silicon wafers. This is another area that can be very lucrative for Intel but is likely to take a great deal of time. Nvidia's overall strategy is to combine hardware and software, algorithms and other services. Nvidia has benefited from being the first to offer various

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<sup>17</sup><https://www.bloomberg.com/news/articles/2023-06-28/us-plans-new-ai-computer-chip-export-controls-aimed-at-nvidia>

products, such as the GPU, Computer Unified Device Architecture (CUDA), and created the first deep learning hardware accelerators, such as the Tesla V100 T4 GPUs (data center GPUs). Another facet of Nvidia's strategy has been to prioritize the quality of its products over the costs of producing them. The GPU, data center and gaming chips consist of the most advanced technology but are more expensive than competing chips. The company also produces its own GPU's and other hardware components and also develops its own software.

Most of NVIDIA'S revenues come from GPU sales, which can be used in many applications, such as gaming, robotics, automotive applications, etc. Unlike NVIDIA, AMD sells cutting-edge technological products such as microprocessors, GPU's, computer hardware, etc. at relatively low prices. AMD has successfully diversified its offerings past the traditional PC market into data centers and gaming markets. This has made the company less reliant on one or two revenue sources. The company has been able to keep up with technological changes and adapt its products to the latest technology. After many years of competing with established firms such as Intel and NVIDIA, AMD is now highly successful and continues to remain highly innovative in this market.

## **An Examination of How Early DEI Policies Have Shaped Current Corporate DEI Practices and Programs By Avery Wu**

### **Abstract**

In recent years, diversity, equity, and inclusion (DEI) practices, programs, and policies have become very prevalent and routine in corporate America. Many companies have tried to create a more welcoming and inclusive environment for their employees because of the potential benefits of these initiatives. Companies implementing DEI within their business could experience higher revenue and profits, higher company morale, greater diversity of ideas, views, and opinions, and an enhanced appeal to potential employees. This research paper aims to analyze and explain how early DEI policies have affected corporate DEI practices and programs today. By researching and examining statistics, documents, and research articles, this study will describe the evolution of the earliest DEI policies in the US. I will specifically focus on three early DEI policies, including the Equal Pay Act of 1963, Title VII of the Civil Rights Act of 1964, and affirmative action. These three early initiatives have been key to the fundamental goal of diversifying the workforce and creating equal opportunity for all. This paper will provide insights into the past, present, and future of DEI in the corporate world by analyzing the causes and effects of the earliest DEI policies. The findings of this study can be utilized by corporations, the US government, and employees to achieve the goal of fostering inclusive and equitable environments that benefit employees, businesses, and society as a whole.

Injustice and discrimination have always existed. People have been wrongly judged based only by their social class, socioeconomic status, ethnicity, race, gender, religion, and sexual orientation. Change was required to level these imbalances. The diversity, equity, and inclusion (DEI) movement was formed in the 1960s to remedy such injustices. DEI has “its roots in the 1960s civil rights movement” and focused on recognizing the achievements of racial and ethnic minorities (Edmunds and Lind 1). Diversity, equity, and inclusion are often grouped together because of their apparent similarities. Although they may seem similar, they have very significant differences that should first be acknowledged. According to Lisa Dunn’s article, diversity is defined as acknowledging all the ways people differ. Although equity is commonly interchanged with equality, there are key differences between the two: “where equality is a system in which each individual is offered the same opportunities regardless of circumstance, equity distributes resources based on needs” (Dunn). Inclusion takes diversity a step further; it is the actual act of welcoming and supporting all individuals.

Now that diversity, equity, and inclusion have been properly defined, discussing DEI specifically in corporate America is necessary. Although the DEI movement began in the 1960s, DEI in corporate America gained popularity in the 1980s when most big employers had hired

equal opportunity managers and the creation of workshops, programs and special groups began for women and minorities. (Dobbin et al. 23). Back then, the main focus was to increase the number of women in top jobs (Williams et al. 440), as “women in senior leadership are 60% more likely to provide emotional support to employees and 24% more likely to ensure their teams’ workloads are manageable” (Berg and Miller 2). With more women choosing to work, there was a need for more representation in senior positions. Currently, DEI in the workplace is a much bigger umbrella term for various programs, positions, and policies that companies enforce to create a more diverse and inclusive environment. However, these programs, positions, and policies could not have been created without the foundational framework of early DEI policies in the 1960s. Therefore, this research paper analyzes the effects of early DEI policies, including the Equal Pay Act of 1963, Title VII of the Civil Rights Act of 1964, and affirmative action in modern business. To ensure the longevity of DEI in the workplace, it is important to understand past initiatives' problems, challenges, and successes.

There are plenty of benefits to implementing DEI in a company. Hiring employees from diverse backgrounds can increase profits, reduce turnover, and increase employee productivity, creativity, and innovation (Williams et al. 440). Although many companies take actionable steps to ensure all employees feel welcomed, others include DEI to sound more appealing to consumers. Because DEI is currently such a hot topic of discussion, some companies feel pressured to add something relevant to DEI on their websites, advertisements, and other materials to merely keep up with other companies. The facade of DEI often misleads individuals who view these companies from the outside, which could be especially harmful to prospective employees looking to work in an inclusive and welcoming environment. More recently, because of these illusions, the term DEI in corporate America has started to lose credibility and traction from various industries such that “American workers are split on the importance of a diverse workforce, surveys find” (Chen and Weber). As a result, companies put less money every year into DEI programs and positions. A recent article stated, “In the wake of George Floyd’s murder in police custody in May 2020, companies scrambled to hire chief diversity officers, changing the face of the C-suite” (Chen and Weber). Today, CDOs are quitting or getting laid off due to the decreasing budget and lack of control. In a survey of 138 diversity executives, 82% said they had sufficient influence to do their job, down 6% from 2022 (Chen and Weber). Many individuals working in corporate America do not know what role diversity, equity, and inclusion efforts will play in the future.

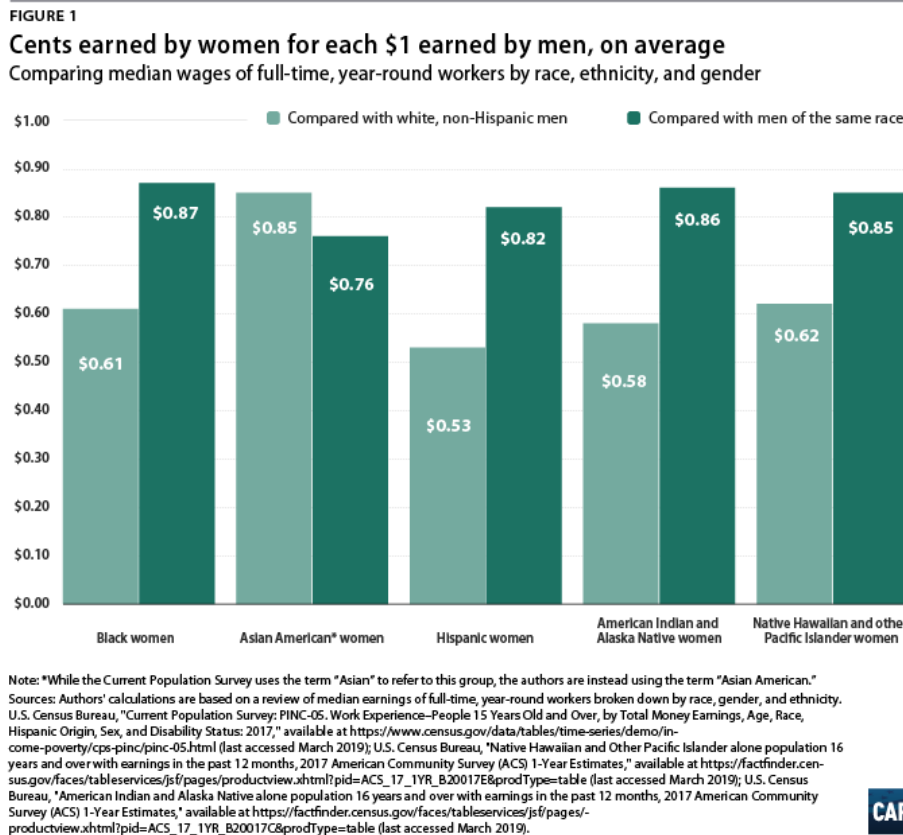
### **Commissions and Committees**

A specific US commission, the Equal Employment Opportunity Commission (EEOC), aids in creating and establishing many early and current DEI laws. The EEOC was established to protect all individuals in the workplace by enforcing laws to limit discrimination based on race, color, religion, and sex. Unfortunately, before 1963, employees were not protected during the hiring process, from wrongful termination, or from discrimination due to their identities (Maness and Conway-Klaassen 41). However, since its establishment, the EEOC has become the primary

enforcer of employment discrimination law in the United States for decades. The EEOC has played a part in enacting the Equal Pay Act, the Civil Rights Act, and the Pregnancy Discrimination Act (U.S. Equal Employment Opportunity Commission). The EEOC continues to play a significant role in fighting for the rights of millions of working Americans.

### Equal Pay Act of 1963

The Equal Pay Act of 1963 was one of the very first DEI laws created to fight the wage discrepancy, mainly between men and women. The Equal Pay Act, signed by President John F. Kennedy, prohibited discrimination on account of sex in the payment of wages by employers engaged in commerce or the production of goods for commerce (U.S. Equal Employment Opportunity Commission). Women are known to earn less money than men even though they are working the same job. Wage secrecy, the impracticality of suing, and the strength of current laws are just a few reasons this continues (Maness and Conway-Klaassen 39). Research found that in 2014, women working full-time earned only 79 percent compared to what the man earned working full-time. African American and Latina women faced larger pay gaps; African American women earned 64 cents and Latina women earned 56 cents for every dollar earned by a white non-Hispanic man (Merluzzi). The figure below, from the Center for American Progress, breaks down each race, ethnicity, and gender and their median wages in 2019, where racial/ethnic and gender wage disparities are evident.



Unfortunately, the Equal Pay Act of 1963 has not entirely served its purpose in corporate America as President Kennedy hoped. Although this is a federal law, there continues to be an ongoing and obvious wage discrepancy. However, there are some positives within individual companies striving to create DEI in their businesses. In 2016, 28 companies signed President Obama's Equal Pay Pledge to share their commitment to equal pay (Merluzzi). Some of these companies include Amazon, American Airlines, Spotify, and Pepsi. With an increasing number of women and minorities working, these companies have promised to support gender and racial balance and work towards equal pay for all.

Multiple organizations have been created outside of individual businesses to fight wage discrimination in America. Founded in 1974, the Equal Rights Advocates (ERA) organization is one of the earliest examples. Today, the ERA includes not only men and women but also the LGBTQ+ community. The ERA fights unequal workplace pay by helping enact civil rights laws and providing free legal help to those in need. Not only do they focus on equal pay, but they also advocate for ending sexual harassment in the workplace.

### **Title VII of the Civil Rights Act of 1964**

Title VII of the Civil Rights Act of 1964 is considered the most important equal opportunity law enacted because it prohibits discrimination based on skin color, religion, gender, or national origin (Etools4Education). During Kennedy's presidency, he advocated for and announced major civil rights legislation at the request of civil rights leaders across America (National Parks Service). After President Kennedy's assassination, President Lyndon Johnson ensured that the Civil Rights Act would take effect immediately after it passed through Congress. The Minnesota Journal of Law and Inequality has concluded that between 1967 and 1984, Title VII's enforcement narrowed the sex differential in earnings by 7.1%. Although this number may seem insignificant, these types of DEI policies are designed to last a very long time and develop with the changing society and views.

Many individuals today view Title VII of the Civil Rights Act as somewhat effective over the 60 years it has been in place. In response to Title VII of the Civil Rights Act, many companies have created special programs designed to eliminate discrimination and stereotypes in the workplace. Companies in the 80s and 90s also used Title VII to "protect against and settle civil rights suits" (Vaughn). Almost every major company in America has adopted programs such as mentoring programs, affinity groups/employee resource groups (ERG), and diversity training. Starting in the 1980s and continuing into the 1990s, businesses expanded to include other identity groups, such as religious and LGBTQ+ groups (Vaughn). Mentoring programs were created to connect senior and junior employees with the same attributes and characteristics, such as race, ethnicity, and religion, and to uplift and support one another within the company. Mentoring programs and diversity managers are primarily successful in increasing the number of women and minorities working (Dobbin et al. 26).

Although affinity groups serve the same purpose as mentoring programs, they have not been perceived as successful. Affinity groups can create an unwanted culture of discrimination



for individuals who feel left out of a particular group, which can cause workplace friction and tension. In 2007, Frank Dobbin and colleagues wrote that hiring a diversity manager or creating a task force is one of the most effective ways to promote DEI within a company. Today, “the number of CDO searches is down 75% in the past year,” and demand is the lowest in 30 years (Chen and Weber). This demonstrates how up and down and volatile some DEI trends can be in the workplace over time.

### **Affirmative Action**

In 1961, President Kennedy signed Executive Order 10925 to show the government’s commitment to equal opportunity for all employed Americans. Specifically, “Affirmative action is defined by [...] the obligation on the part of the contractor to take action to ensure that applicants are employed, and employees are treated during employment, without regard to their race, color, religion, sex, sexual orientation, gender identity, national origin, disability, or status as a protected veteran” (U.S. Department of Labor). Affirmative action in schools and universities has also become widely controversial due to the recent Supreme Court rulings and “remains a highly contentious political issue and debate topic” (Tomar).

Since being enacted, affirmative action has taken many forms in businesses, schools, universities, and other organizations and has seen a rise in favorability (58%) over the years among people of color and other minorities (Just Great Lawyers). Women and other racial and ethnic minorities like Black and Native Americans have experienced major success from affirmative action in education and the workplace. Between 1973 and 2003, the employment share increased from 4.7 to 5.8 percent for Black women and 2.1 to 4.4 percent for Hispanic women (Kurtulus 1). In addition to hiring practices, affirmative action uses various methods to promote equal opportunity, such as trainings, outreach, and equal pay policies (Ferguson). Employers have utilized training programs specifically to combat workplace discrimination and bias. Managers or other employees typically participate in training programs to learn how to eliminate bias and stereotypes when hiring new employees and create an inclusive, welcoming environment for all existing employees. However, training programs have not been perceived as successful because these trainings often do not have the proper amount of time allocated to them, and many individuals see them as a one-time event that they will ultimately forget about (Eleven Recruiting). After the 2023 *Students for Fair Admissions v. President and Fellows of Harvard College* Supreme Court ruling, there have been major concerns for the future of Corporate America. Some of the largest companies, including G.M. and Meta, have argued that the elimination of affirmative action will make it harder to build diverse workforces. (Ross Sorkin et al.).

Affirmative action in the workplace remains a complex and contentious issue that continues to spark debate among policymakers, scholars, and the general public. While it has made significant strides in promoting diversity and addressing historical inequalities, it also faces criticism for potential reverse discrimination and concerns about its effectiveness.

## **Conclusion**

These initiatives formed in the 1960s have profoundly shaped society's progress on diversity, equity, and inclusion. While these multifaceted laws have not done nearly enough to ensure DEI within the workplace, there have been countless positives that have stemmed from these early policies. They have not only fostered a more inclusive environment for all American employees but also challenged and brought to light the inequities in the outdated systems and structures of Corporate America.

Over the decades, the Equal Pay Act of 1963 has paved the way for greater economic fairness, providing a legal framework to challenge pay discrimination based on gender. While progress has been made, challenges persist, and there is still work to be done to fully close the gender pay gap. Title VII has not only opened doors of opportunity for countless individuals who were previously marginalized but has also played a vital role in shaping corporate culture and promoting diversity and inclusion in the workplace. Creating multiple programs and positions has been hit or miss but still proves many companies' commitment to creating an inclusive environment. While affirmative action was designed to eliminate bias in the workplace, it has evolved to include other organizations, mainly top-tier universities. The Supreme Court decision will no doubt affect and change the way Corporate America structures its DEI efforts.

These policies were created in response to the demand for change in the workplace. Women and minorities especially have been fighting the uphill battle of discrimination and bias for decades. Continued dedication to evaluating, refining, and implementing DEI policies is vital for Corporate America to move closer to the goal of fostering inclusive and equitable environments that benefit employees, businesses, and society as a whole.

## Works Cited

- Beller, Andrea H. "The Effects of Title VII of the Civil Rights Act of 1964 on Women's Entry into Nontraditional Occupations: An Economic Analysis ." *Minnesota Journal of Law and Inequality*, June 1983,  
[scholarship.law.umn.edu/cgi/viewcontent.cgi?article=1267&context=lawineq](http://scholarship.law.umn.edu/cgi/viewcontent.cgi?article=1267&context=lawineq).
- Berg, Kati Tusinski, and Katharine E. Miller. "Leading the charge: Female leaders advance DEI initiatives through employee empowerment." *Journal of Public Relations Research*, 2023, pp. 1-18.
- Chen, Te-Ping, and Lauren Weber. "The Rise and Fall of the Chief Diversity Officer." *The Wall Street Journal*, 21 July 2023, [www.wsj.com/articles/chief-diversity-officer-cdo-business-corporations-e110a82f](http://www.wsj.com/articles/chief-diversity-officer-cdo-business-corporations-e110a82f).
- Dobbin, Frank, Alexandra Kalev, and Erin Kelly. "Diversity management in corporate America." *Contexts*, vol. 6, no. 4, 2007, pp. 21–27.
- Dunn, Lisa. "What Is Diversity, Equity & Inclusion (Dei)?" *InclusionHub Digital Inclusion Resources*, 6 Nov. 2020,  
[https://www.inclusionhub.com/articles/what-is-dei#:~:text=Diversity%2C%20Equity%20%26%20Inclusion%20\(DEI\)%20encompasses%20the%20symbiotic%20relationship,By%20Lisa%20Dunn](https://www.inclusionhub.com/articles/what-is-dei#:~:text=Diversity%2C%20Equity%20%26%20Inclusion%20(DEI)%20encompasses%20the%20symbiotic%20relationship,By%20Lisa%20Dunn).
- Edmunds, Margo, and Lind, Dorcas. "Glossary of Definitions and Core Concepts for Diversity, Equity, and Inclusion (DEI)." *AcademyHealth*, 9 August 2021,  
[https://academyhealth.org/sites/default/files/publication/%5Bfield\\_date%3Acustom%3AY%5D-%5Bfield\\_date%3Acustom%3Am%5D/deiglossary\\_nov\\_2021\\_1.pdf](https://academyhealth.org/sites/default/files/publication/%5Bfield_date%3Acustom%3AY%5D-%5Bfield_date%3Acustom%3Am%5D/deiglossary_nov_2021_1.pdf)
- Eleven Recruiting, "11 Reasons Why Training and Development Fails ." 15 Apr. 2023,  
[elevenrecruiting.com/why-training-and-development-fails/#:~:text=Sometimes%2C%20the%20work%20culture%20in,resources%20to%20use%20the%20skills](http://elevenrecruiting.com/why-training-and-development-fails/#:~:text=Sometimes%2C%20the%20work%20culture%20in,resources%20to%20use%20the%20skills).
- Etools4Education, "Title VII.",  
<https://www.online-distance-learning-education.com/title-%20vii.html#:~:text=Title%20VII%20is%20considered%20to,gender%20or%20their%20national%20origin.%20Accessed%2021%20Aug.%202023>.
- Ferguson, Jackie. "Why We Still Need Affirmative Action, Especially in the Workplace." *Forbes*, 21 Mar. 2023,  
[www.forbes.com/sites/forbesbusinesscouncil/2023/03/21/why-we-still-need-affirmative-action-especially-in-the-workplace/?sh=2638d2c226c1](http://www.forbes.com/sites/forbesbusinesscouncil/2023/03/21/why-we-still-need-affirmative-action-especially-in-the-workplace/?sh=2638d2c226c1).
- Just Great Lawyers, "Affirmative Action Statistics and Facts after 50 Years." 18 Nov. 2021,  
[www.justgreatlawyers.com/legal-guides/affirmative-action-statistics-facts](http://www.justgreatlawyers.com/legal-guides/affirmative-action-statistics-facts).
- Kurtulus, Fidan Ana. "The impact of affirmative action on the employment of minorities and

- women: a longitudinal analysis using three decades of EEO-1 filings." *Journal of Policy Analysis and Management*, 35, 1, 2016, 1-34.
- Maness, Lisa, and Janice Conway-Klaassen. *Laws to Protect Diverse Employees*, 2017, [dpl6hyzg28thp.cloudfront.net/media/Laws\\_to\\_Protect\\_Diverse\\_Employees.pdf](https://dpl6hyzg28thp.cloudfront.net/media/Laws_to_Protect_Diverse_Employees.pdf).
- Merluzzi, Natalia. "These Businesses Are Taking the Equal Pay Pledge." *National Archives and Records Administration*, 14 June 2016, [obamawhitehouse.archives.gov/blog/2016/06/14/businesses-taking-equal-pay-pledge](https://obamawhitehouse.archives.gov/blog/2016/06/14/businesses-taking-equal-pay-pledge).
- National Parks Service, "The Kennedys and the Civil Rights Movement (U.S. National Park Service).", 12 Sept. 2021, [www.nps.gov/articles/000/the-kennedys-and-civil-rights.htm#:~:text=President%20Kennedy%20defined%20civil%20rights,and%20require%20public%20schools%20to](https://www.nps.gov/articles/000/the-kennedys-and-civil-rights.htm#:~:text=President%20Kennedy%20defined%20civil%20rights,and%20require%20public%20schools%20to).
- Portocarrero, Sandra, and James T. Carter. "Diversity initiatives in the US workplace: A brief history, their intended and unintended consequences." *Sociology Compass*, vol 16, no. 7, 2022, pp. 1-12.
- Ross Sorkin, Andrew, et al. "Why Corporate America Is Worried about Affirmative Action." *The New York Times*, 30 June 2023, [www.nytimes.com/2023/06/30/business/dealbook/corporate-diversity-affirmative-action.html#:~:text=Over%2060%20big%20companies%2C%20including,harder%20to%20build%20diverse%20workforces](https://www.nytimes.com/2023/06/30/business/dealbook/corporate-diversity-affirmative-action.html#:~:text=Over%2060%20big%20companies%2C%20including,harder%20to%20build%20diverse%20workforces).
- Tomar, Dave. "Controversial Topic: Affirmative Action." *Academic Influence*, 4 June 2021, [academicinfluence.com/inflection/controversial-topics/controversial-topic-affirmative-action](https://academicinfluence.com/inflection/controversial-topics/controversial-topic-affirmative-action).
- U.S. Department of Labor, "Affirmative Action Frequently Asked Questions." [www.dol.gov/agencies/ofccp/faqs/AAFAQs#:~:text=Affirmative%20action%20is%20defined%20by,%2C%20national%20origin%2C%20disability%2C%20or](https://www.dol.gov/agencies/ofccp/faqs/AAFAQs#:~:text=Affirmative%20action%20is%20defined%20by,%2C%20national%20origin%2C%20disability%2C%20or). Accessed 3 Sept. 2023.
- U.S. Equal Employment Opportunity Commission, "The Equal Pay Act of 1963." [www.eeoc.gov/statutes/equal-pay-act-1963](https://www.eeoc.gov/statutes/equal-pay-act-1963). Accessed 12 Aug. 2023.
- Vaughn, Billy E. "The History of Diversity Training & Its Pioneers." *Diversity Officer Magazine*, spring 2007, [diversityofficermagazine.com/diversity-inclusion/the-history-of-diversity-training-its-pioneers/#:~:text=While%20gender%20diversity%20education%20began,appear%20in%20education%20and%20training](https://diversityofficermagazine.com/diversity-inclusion/the-history-of-diversity-training-its-pioneers/#:~:text=While%20gender%20diversity%20education%20began,appear%20in%20education%20and%20training).
- U.S. Equal Employment Opportunity Commission, "What Laws Does EEOC Enforce?" [www.eeoc.gov/youth/what-laws-does-eeoc-enforce#:~:text=Title%20VII%20of%20the%20Civil,identity\)%2C%20or%20national%20origin](https://www.eeoc.gov/youth/what-laws-does-eeoc-enforce#:~:text=Title%20VII%20of%20the%20Civil,identity)%2C%20or%20national%20origin). Accessed 3 Sept. 2023.
- Williams, Christine L., Kristine Kilanski, and Chandra Muller. "Corporate diversity programs and gender inequality in the oil and gas industry." *Work and Occupations*. vol. 41, no. 4, 2014, pp. 440-476.

## **Accommodations for Employees with Cancer in the Workplace By Sonya Bhagwan**

### **Abstract**

As improvements in cancer treatment continue to develop, survivor rates are increasing; thus, the number of people returning to and staying at work is also growing. Although employees impacted by cancer would likely benefit from workplace accommodations, there has been little research on what an optimal cancer accommodation program entails. Moreover, each employee's circumstance varies, so the program must be flexible enough to account for the specific needs of each cancer survivor. This paper investigates various factors relevant to designing a program for employees impacted by cancer.

### **Introduction**

In recent years, there has been a notable improvement in the field of cancer treatment, leading to a rise in survival rates for cancer patients. This encouraging trend has significantly increased the number of cancer survivors returning to the workforce after completing their treatments (Taskila & Lindbohm, 2007). As an increasing number of cancer survivors return to professional life, it has become crucial for employers and organizations to recognize the importance of providing suitable workplace accommodations. However, despite the growing number of cancer survivors rejoining the workforce, extensive research on the most effective and optimal cancer accommodation programs appears to be lacking.

A workplace that understands and actively implements such accommodations can support cancer survivors, enabling them to thrive in their roles while managing their health challenges. But despite the importance of these accommodation programs, comprehensive research remains scarce in this area. While there may be some general guidelines and recommendations available, there is a need for more tailored and evidence-based approaches to cater to the specific needs of each cancer survivor. Since every individual's cancer journey is unique, accommodating them based on their circumstances, treatment types, and ongoing health requirements becomes crucial (Stergiou-Kita et al., 2016).

The literature review on workplace accommodations for cancer survivors reveals a growing body of research aimed at understanding and improving the work experiences of individuals who have undergone cancer treatment. Research highlights the positive impact of workplace accommodations on cancer survivors' overall well-being and job performance. (Stergiou-Kita et al., 2016). Accommodations can lead to reduced fatigue, increased job satisfaction, and higher productivity levels among employees with a history of cancer. Cancer is a complex disease with many physical and psychological effects. More research is needed to understand the specific accommodation needs of different cancer types and stages.

## **Methodology**

The sample size of this study was ten participants, six of whom were men, and four of whom were women. The study was open to all demographics, although data on race/ethnicity and age was not specifically collected. The participants were recruited by posting on online groups centered around different types of cancer (Sickle Cell, Leukemia, Rectal, Basal Cell, Thyroid, and Breast Cancer). This diverse sample was chosen to include the perspectives of employees with various types of cancer.

Each participant completed an online Google form survey with eight questions. The initial questions verified that the participant had been diagnosed with cancer and if they had been in the workplace while being impacted by cancer. The remaining questions were open-ended, asking about their satisfaction levels with the accommodations provided by their employer. Participants were also given the option to participate in a recorded interview in which they would expand on their experience. Each participant was compensated with \$20 for completion of the survey. \*View survey questions in the Appendix\*

## **Analysis and Results**

In the analysis of participant responses, it is evident that there was a wide range of satisfaction levels regarding the accommodations provided. Notably, five individuals expressed extreme satisfaction with their accommodations, indicating that the support met or exceeded their expectations. One participant stated, “The accommodations provided were all super helpful, they made my life easier at the workplace and also made me very comfortable and in a safe place. I was able to work from home and whenever I went back to the office I was able to feel the love and care of my employer and co-workers.” Two participants reported being somewhat satisfied, suggesting there may have been room for improvement in their accommodations. However, a concerning finding was that three individuals expressed extreme dissatisfaction with their accommodations. One participant recounted: “My manager was very hesitant to give me time off. When he finally agreed to, he only gave extra work breaks for 1 month. I was still receiving treatment, yet he did not allow me to telecommute or have extended time off. I didn't feel safe or comfortable at work, and I almost lost my job due to not being able to complete tasks on time, even though I had always been a responsible employee before being diagnosed.” This distressing account reveals that the participant's manager was hesitant to provide adequate time off, leading to difficulties in managing medical treatments and work responsibilities, ultimately jeopardizing their job. Despite these mixed experiences, it is worth noting that most participants were granted flexible scheduling and modifications in their work duties, potentially contributing to their overall satisfaction. Additionally, telecommuting was generally permitted, though extended paid time off and extra work breaks were less frequently provided, indicating room for improvement.

## **Discussion**

The analysis of participant responses in this study reveals the need for improved accommodations for cancer patients in the workplace. One of the most striking findings is the disparity in satisfaction levels among respondents. While a majority of five individuals reported extreme satisfaction with the accommodations provided, there were also notable instances of intense dissatisfaction, as indicated by three participants. These disparities in satisfaction levels suggest significant room for improvement in how employers support employees with cancer. (Hansen, 2008).

The implication of these mixed satisfaction levels is twofold. First, it underscores the importance of tailoring accommodations to individual needs. Not all cancer patients have the same requirements, and employers need to adopt a flexible approach that addresses the specific challenges each employee faces during their cancer journey. Second, it highlights the need for greater awareness and education among employers and managers about the diverse needs of employees with cancer. Clear communication and understanding can lead to more effective accommodations that enhance the well-being and productivity of these employees.

The experiences shared by participants also underscore the potential consequences of inadequate accommodations. Several participants mentioned challenges in maintaining their job performance due to insufficient support. For instance, one participant nearly lost their job because they could not complete tasks on time despite previously being a responsible employee. This situation negatively impacted the employee's well-being and had potential financial implications for the employer due to decreased productivity and the potential costs associated with recruitment and training of new employees. Thus, the impact of inadequate accommodations are personal and extend to organizational efficiency and effectiveness.

The findings of this study align with previous research that has highlighted the importance of accommodations for cancer patients in the workplace. Previous studies have shown that accommodating cancer employees can improve job satisfaction, higher retention rates, and enhanced overall well-being. However, the current study adds nuance to these findings by revealing the significant variations in accommodation experiences among cancer patients.

One notable discrepancy is the relatively low number of participants provided with extended paid time off and extra work breaks. This finding contrasts with previous research suggesting that such accommodations can significantly benefit cancer patients by allowing them the time and space needed for medical treatments and recovery. The low incidence of these accommodations in our study raises questions about whether employers are fully aware of the benefits of providing extended paid time off and breaks or if organizational barriers are preventing their implementation.

Moreover, the accounts of participants experiencing resistance and hesitation from their managers in providing accommodations echo the findings of previous studies that have highlighted the role of managerial support in facilitating accommodations for employees with cancer. The change in management mentioned by one participant is a particularly concerning issue as it suggests a lack of consistency and understanding within the organization regarding the importance of accommodating cancer patients. Based on the findings of this study and the

broader research on workplace accommodations for cancer patients, several recommendations can be made for designing an optimal cancer accommodation program:

**Customization:** Recognize that not all cancer patients have the same needs. Develop a personalized approach to accommodations, considering each employee's specific requirements and challenges. This can be achieved through open and empathetic communication with the employee and their healthcare providers.

**Flexibility:** Foster a culture of flexibility within the organization. Cancer patients may require different accommodations at different stages of their treatment and recovery. Encourage managers to be adaptable and responsive to changing needs. (Stergiou-Kita et al., 2016).

**Clear Policies:** Establish clear and comprehensive accommodation policies and procedures within the organization. These policies should outline the process for requesting accommodations and ensure that employees know their rights and the support available to them (DeFreitas, n.d.).

**Regular Check-Ins:** Implement regular check-ins with employees who require accommodations. This can help assess the effectiveness of the accommodations and make adjustments as needed. It also provides a platform for employees to express their concerns and needs.

**Extended Paid Time Off:** Given the potential lengthy treatment and recovery periods associated with cancer, consider offering extended paid time off options. This can alleviate financial stress and enable employees to focus on their health and well-being.

The importance of flexibility cannot be overstated when it comes to accommodating cancer patients in the workplace. The diverse experiences and challenges highlighted by the study participants underscore the need for employers to be adaptable and responsive to individual employee needs. Flexibility should extend beyond the initial accommodation decision and continue throughout the employee's journey with cancer. Employers should be prepared to adjust accommodations as the employee's condition evolves or as they transition through different phases of treatment and recovery. Regular check-ins and open communication with the employees can facilitate this process and ensure that accommodations remain effective and supportive.

The findings of this study emphasize the significance of providing accommodations to all cancer patients in the workplace. While some individuals reported high levels of satisfaction with the accommodations they received, there is a clear need for greater awareness, customization, and flexibility in accommodating the diverse needs of employees with cancer. By implementing the recommendations outlined above, organizations can create a more supportive and inclusive work environment for employees facing the challenges of cancer. Ultimately, such efforts can improve employee well-being, job satisfaction, and organizational success.

## **Conclusion**

In summary, this study reveals a diverse landscape of workplace accommodations for cancer patients, with varying satisfaction levels among participants. The findings underscore the



critical importance of developing effective and flexible cancer accommodation programs in the workplace. Such programs enhance employee well-being and job retention and contribute to increased productivity and a more inclusive organizational culture. The study also highlights the need for ongoing research to explore the long-term effects of accommodations, improve managerial training, analyze regional and sector-specific differences, and assess these programs' psychosocial and financial impacts. Ultimately, these insights can guide organizations in providing more comprehensive and tailored support to employees facing cancer diagnoses, fostering a more inclusive and supportive work environment.

## Appendix

### Survey Questions:

1. Have you been diagnosed with cancer?
2. Have you ever held a job while being impacted by cancer (whether this was during treatment and/or post-recovery)?
3. Did your employer provide accommodations based on your situation? Please check the specific accommodations that you received (if any).
4. How long were these accommodations provided for you?
5. On a scale of 1-10, how satisfied were you with the accommodations your employer provided? (1=extremely dissatisfied 10=extremely satisfied). Expand on the number you chose. What accommodations were helpful? Were there any accommodations you wish you were provided with? Please be as detailed as possible.
6. On a scale of 1-10, how understanding were your coworkers of your situation? Did they support you throughout your experience? (1=extremely dissatisfied 10=extremely satisfied)
7. Would you be interested in participating in a video-recorded interview detailing your experience? By selecting 'Yes', you are not fully committing to doing the interview, you are simply expressing interest in being contacted in the future about potential participation.
8. Where did you find this survey?

### Works Cited

- Hansen, J. A., Feuerstein, M., Calvio, L. C., & Olsen, C. H. "Breast Cancer Survivors at Work." *Journal of Occupational and Environmental Medicine*, vol. 50, no. 7, 2008, pp. 777–784. <http://www.jstor.org/stable/44997589>.
- Stergiou-Kita, M., Pritlove, C., van Eerd, D. et al. "The provision of workplace accommodations following cancer: survivor, provider, and employer perspectives." *Cancer Survivor*, vol. 10, 2016, pp. 489–504. <https://pubmed.ncbi.nlm.nih.gov/26521166/>.
- T. DeFreitas (n.d.). "Tell 'Em About It: Educating the Workforce About the ADA & Accommodations." *Job Accommodation Network*. Accessed September 15, 2023. <https://askjan.org/articles/Tell-Em-About-It-Educating-the-Workforce-about-the-ADA-and-Accommodations.cfm>.
- T. Taskila & M. L. Lindbohm. "Factors affecting cancer survivors' employment and work ability." *Acta Oncologica*, vol. 46, no. 4, 2007, pp. 446-451. <https://doi.org/10.1080/02841860701355048>

## **Suffering in Chinese Buddhism and Italian Christianity: Comparison Between Northwestern Chinese Mogao Grottoes and Italian Christian Artworks By Sherry Mi**

### **Introduction**

Visual art is one of the easiest ways to communicate, while the spread of a religion depends on the diffusion of its beliefs, which solely depends on communication. For this reason, artists have created countless religious works in the past millennia. Furthermore, the use of religious symbols increased as religions, usually including scriptures, holy figures, and taboos, were systematized. Symbols convey essential religious ideas to the viewers, including suffering.

In my 2020 visit to the Mogao Grottoes in Northwestern China, I also noticed that Buddhist stories of sacrifice and suffering were also one of the most depicted images. Religious beliefs, I conjectured, supplement images of suffering, delivering an important lesson about pain to the followers: Why is pain present? How can one cope with it? Notably, religious art only represents the opinions of its artist, probably on behalf of society, but not God. Opinions may change over time.

I soon discovered that these images were produced inconsistently as the religion evolved. I recorded my discoveries in Buddhist and Christian art in the following analysis. As the religion developed, religious art deviated from images of suffering. The reduction of such images hinted at a transformation of the invisible relationship between religion and society.

What force could drive this palpable change? I noticed similar trends in the development of Chinese Buddhist and Italian Christian art: images of suffering were abundant for one historical period, but declined as the next period began. I also wondered if Buddhist and Christian artists interpreted suffering similarly by making similar artistic choices. This analysis is a possible answer.

The following essay introduces Buddhism and Christianity's origin and their development in China and Italy respectively. Then, it conducts three case studies: each study compares a mural from the Mogao Grottoes and an Italian artwork on their interpretations of suffering.

*The geographic names in the essay are from the modern administrative map unless specified: for instance, "Italy" refers to the geographic area of modern-day Italy, and "Rome" refers to that of Italy's capital; the "Roman Empire", however, is the territory ruled by Roman emperors from 27 BC to 476 AD.*

### **Cultural Background**

Siddhartha Gautama (c. 563-c. 483 BC), also known as Shakyamuni (Sanskrit: "the sage of the Shakya clan") or the Buddha (Sanskrit: "Awakened One"), founded Buddhism in India

around the 5th century BC (Lopez). Buddhists define life as an eternal cycle of suffering and rebirth. The only way to escape this cycle is through enlightenment: one needs to abandon their desires because they are the source of pain.

Buttressed by the fundamental Buddhist ideas, Mahayana Buddhism aims to illuminate large communities and extricate them from suffering. It was introduced into China during the Eastern Han Dynasty (25-220 AD). It then accommodated domestic Chinese beliefs, such as those in Confucianism and Taoism, and transformed into Han Buddhism, a type of Mahayana Buddhism that rulers and society widely accepted (“Buddhism in China”).

Buddhism coexisted with its art: the religion was known as *xiangjiao* (像教), literally “the religion of image”, during its early development in China (Greene). Followers created Buddhist art both as a product of their reverence and as a medium to edify more civilians about the religion. Some artworks illustrate the stories of Buddha Shakyamuni in his previous and current incarnations; others visualize scenes in Buddhist scriptures.

Along with the fall of the Eastern Han Dynasty came a tumult that lasted for more than 160 years (c. 220-386 AD). It ceased in the Northern Wei Dynasty (386-534 AD, Map 1) when Buddhism thrived and was “utilized as a theocratic power for ideological and social control of the predominantly Chinese population”. The court encouraged civilians to carry out Buddhist practices rather than to stir further social instability.

During the Tang dynasty (618-907 AD, Map 2), Buddhism and Buddhist art remained popular before the An Lushan rebellion (755 AD). The following essay will name the Tang dynasty before the rebellion “Early/High Tang” because it developed from the early stages to its acme: Under the influence of social stability—relative to the Northern Wei dynasty—and cultural prosperity, Buddhism underwent secularization and thus welcomed more followers.



Map 1: The Northern Wei territory is highlighted in green.  
 Source: SS, "Northern Wei Map."



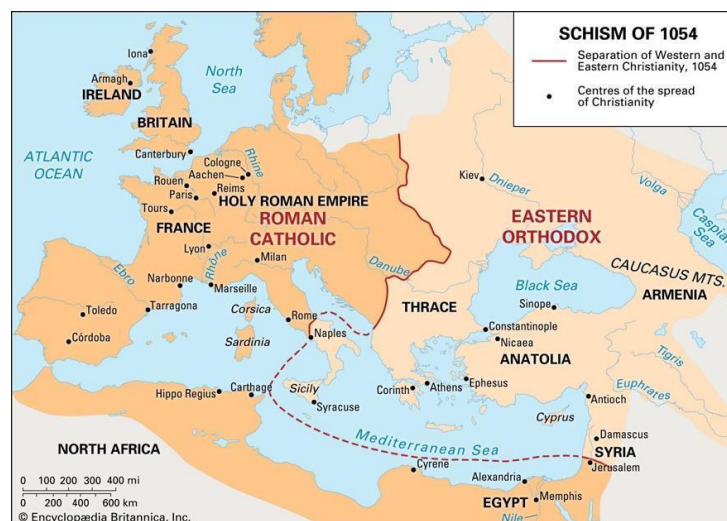
Map 2: Map of Tang dynasty. Tang rulers opened the dynasty to the Silk Road, allowing more trade in northwest China (National Geographic Maps [@natgeomaps]).

Both dynasties reigned over Dunhuang, a city located in the modern-day Gansu province (Map 1-2). As a key city on the Silk Road, Dunhuang fostered Buddhist communication through visual arts. There, Buddhists constructed the Mogao Grottoes, a group of 492 caves on the east cliff wall of Mingsha mountain (UNESCO World Heritage Centre). The caves were built from the 4th century AD until the 14th century AD. Most of them have interior painted murals and statues, while the artists are unknown. The murals analyzed in this essay date to the North Wei Dynasty and the Tang Dynasty.

Similar to Han Buddhism, Christianity was also a foreign religion to the Roman Empire. It developed in the modern-day Middle East, which centered on Jerusalem. Its teachings centered on the Holy Trinity, including the Father, the world's creator; the Son, Jesus Christ; and the Holy Spirit. In the New Testament, Christ is the leader of Christianity and the Savior of humanity. Christ paid for humans' sins through suffering and Crucifixion.

Before the early 4<sup>th</sup> century AD, Christianity was banned in the Roman Empire; many Christians were tortured or martyred by the government. In 312 AD, Christianity was legitimized by Constantine I (r. 306-337 AD) in the Roman Empire and has since then dominated the region. The fall of the Western Roman Empire in 476 AD embarked on the so-called "Middle Ages". Different from the preceding antiquity and the succeeding modern times, the Middle Ages supported control over freedom.

In 1054 AD, Christianity branched into Roman Catholic and Eastern Orthodox (Map 3). Italy, specifically the Vatican City in Rome, remained the center of the Roman Catholic Church. As visualizations of the Bible, medieval artworks imparted Roman Catholic teachings to the predominantly illiterate European population. The Catholic Church stratified and controlled society until the Renaissance ("LibGuides: G8: Medieval Times: Social Structures"). The revived Classical philosophy enhanced Christianity: the rise of humanism attributed the religion to more personal dignity and attention to humanizing characteristics, which were again reflected in artworks.



Map 3. The East-West Schism of Christianity took place in 1054 AD (“Schism of 1054”).



Map 4. Political map of Europe in 1500 AD  
 (“Europe Main Map at the Beginning of the Year 1500”).

The following essay compares two Northern Wei murals from the Mogao Grottoes with two late medieval Christian artworks in Italy, and an Early/High Tang mural with a Renaissance fresco. Though Buddhism and Christianity developed in different locations and at different time intervals, they are comparable because their role in politics and society had transformed similarly.

The Northern Wei dynasty and the late Middle Ages transitioned a society with a strong religious atmosphere as well as tumult to a more secular and stable condition.<sup>1</sup> Proposed by Jixun Wang in his research on Northern Wei Buddhist worship (100), The phenomenon proves an assertion of English essayist Edward Gibbon FRS: “The various modes of worship . . . were all considered by the people, as equally true; by the philosopher, as equally false; and by the magistrate, as equally useful” (Gibbon).

The Early/High Tang and the Renaissance succeeded the Northern Wei dynasty and the Middle Ages, correspondingly. They were politically stable periods in which society accepted personal interests, freedom of will, and religious worship flourished. During these periods, religious sites adorned with paintings and sculptures proliferated. Both Buddhist and Christian arts attracted more viewers, not only nobles but also civilians, and underwent secularization in their corresponding periods.

Having established shared characteristics between pairs of historical periods, the evolutions of Buddhism and Christianity were in many ways similar. Furthermore, would the artistic interpretation of suffering also evolve similarly?



**CASE 1**  
**UNBEARABLE SUFFERINGS AND THE ART OF STOICISM**  
—*Shibi Jataka and Crucifixion*



Fig 1: Cross-sectional view of Cave 254, Northern Wei (386-534 AD); the Shibi Jataka is located on the back wall, the center of this image (Steinhardt).



Fig 2: Anonymous artist(s), *Shibi Jataka*, Northern Wei (386-534), mural. Mogao Grottoes, Dunhuang (“Shibi Jataka Illustration, Mural Painting”).

Cave 254 (Fig 1) was a key cave for North Wei Dynasty Buddhist art research. In the center of the cave is a square-based pillar enshrining a Buddha sculpture. The murals on the cave’s walls contained multiple Jataka Tales (lit. birth), describing the deeds of Shakyamuni in his previous incarnations, making the cave a visual inter-referential system of Buddhist teaching. When Buddhists entered the cave, they walked around the pillar counterclockwise and

appreciated the Jataka Tales chronologically.

The *Shibi Jataka* was painted on the west side of the north wall (Fig 1-2), in which King Shibi of Khurus, a previous incarnation of the Buddha, was assessed by a dove and a predatory eagle transformed by two Hindu gods. King Shibi wished to save both the eagle from hunger and the dove from being prey, so he decided to cut his own flesh to satiate the eagle. On a scale, he tried to balance his flesh with the dove, but he could never, and thus he kept sacrificing.



Fig 3-5: Details of *Shibi Jataka*.

King Shibi's selflessness and stoicism are well reflected in the mural. The artist(s) incorporated a hierarchical scale, emphasizing the king in size and position (Fig 2). The king's most decorated accessory is the crown of kingship; otherwise, he only has a robe and plain clothing underneath. He was half-naked, revealing his youthful, robust torso under the robe. His clothing droops below. He sits sedately, holding the tiny dove in his right hand. He lifts his left calf for the butcher to chop his flesh, his eyes gently falling upon the wound. His pain was reflected by the bystanders: the four chancellors (Fig 3-4), different in age and position, watched on the right. They empathize with the king's physical pain, so they fold their hands and implore him to cease his sacrifice. The queen humbly squats (Fig 5), encircles her arms on his left knee, and begs him to stop. Her clinging pose reveals overt pity and worry. Still, they cannot impede the butcher and the king. His other subjects and the gods watched in admiration.

Therefore, according to their different manners, the characters interpret King Shibi's sacrifice differently: to the King himself, it was a glorious sacrifice for helping others; to the queen and the chancellors, it was an unworthy act because it induces self-harm; to the other subjects and the gods, it was a praiseworthy deed that showcases the King's kindness and selflessness.



Fig 6: Pietro Lorenzetti, *The Crucifixion*, Late Middle Ages (c. 1340 AD), tempera and gold leaf on wood. The Metropolitan Museum of Art, New York City (“Pietro Lorenzetti | The Crucifixion”).

Meanwhile, late medieval artist Pietro Lorenzetti (1280-1348 AD) painted a Christian narrative image in the 1340s. The image, similar to *Shibi Jataka* as a story of suffering, is *The Crucifixion*.

*The Crucifixion* was one of Lorenzetti’s narrative panels about the Passion of Christ (Fig 6). The series could be folded into a diptych, and when opened Christians could read the stories and hold Christ in reverence. It “was designed for someone or some government body with judicial responsibilities” (“Pietro Lorenzetti | The Crucifixion”). This information indicated that the emotions explored in *Crucifixion* were agreed upon by the government and could represent the common visual representation of religious suffering in some instance during the mid-14<sup>th</sup>-century Italy.





Fig 7-9: Details of *Crucifixion*.

Christ, along with two criminals, has both hands nailed to the patibulum and both feet nailed to the vertical beam. On his gaunt torso, the thin skin lines the ribcage underneath. Fixed in such a posture, Christ wrenches the witnesses' minds with his never-ending bloody suffering. Lorenzetti exacerbates the physical pain by creating dynamic blood flow (Fig 7). Christ's blood streams down his arms and drips from his instep. His face has withered into a lifeless gray, drooping because of physical pain. Two arrows with sanguine tails dash toward the leftmost criminal, while Christ has already been shot, arterial blood gushing out between his right ribs. Nevertheless, his halo still glows, indicating the sanctity of his sacrifice and his upcoming revival.

The victims represent the physical pain of Crucifixion, while the witnesses exhibit tremendous mental suffering through their facial expressions (Fig 8), as we could see in *Shibi Jataka*. A group of female saints renders golden halos, luxurious cloaks, and rounded bodies; among them Virgin Mary, whose face is as lifeless as her son's, almost collapses. The others tearfully supported her. The two saints on the right are anguished and do not dare to look at the persecution. A procession of soldiers occupies the other portions (Fig 9), but only the centurion in the left foreground has a halo because he has converted to Christianity. He grievously identified Christ for his companion.

Both *Shibi Jataka* and *The Crucifixion* instruct viewers about how to face suffering. By connecting physical suffering with religious role models, the artists not only admit the inevitability of suffering but also set up the credibility of their message. The witnesses of the artwork embody mental suffering, but only from empathy. However, they grieve more dramatically than the role models, the victims of unbearable physical pain. The artists invite viewers to reason the role model's calmness and discover their solution to suffering: stoicism.

Consequently, the artworks became convincing in their times: one should follow their role model and carry out stoicism under suffering. Because both the Northern Wei dynasty and the Late Middle Ages nearly a thousand years later were tumultuous periods, the message was

helpful to those suffering from war and depression. Governments and churches accounted for religious dissemination, so they possibly intended the message to advise their subjects and calm them down by cultivating stoicism.

## CASE 2

### THE ENLIGHTENED AND THE EVIL

—*Illustration of Mara's Defeat and The Last Judgment by Giotto*



Fig 10: Anon artist(s), *Illustration of Mara's Defeat*, Norther Wei (386-534). Mogao Grottoes, Dunhuang. 遥远经典 近在眼前. “【神游千年，大美敦煌】北魏-254窟【2】南壁+动画《降魔成道》(敦煌研究院出品)【高清大图.” *Zhihu*, July 22, 2019, <https://zhuanlan.zhihu.com/p/74613424>.

The good and the evil is one of the most appealing topics in religion. Buddhism and Christianity note the inevitability of suffering, either because of personal desires or the original sin. However, a person can learn teachings and do good to escape pain: in Buddhism, it is known as nirvana, liberation from the cycling pain, and in Christianity, it is rising to heaven in the afterlife. Those who remain mediocre or evil will continue to suffer unless they repent.

*Illustration of Mara's Defeat* was adjacent to *Shibi Jataka* in Cave 254 (Fig 10). It depicted the enlightenment of the Buddha Shakyamuni: he abandoned his desires and “[felt] the bliss of deliverance” under the Bodhi tree for seven days and eventually attained nirvana.





Fig 11-13. Details of *Illustration of Mara's Defeat*.

In the center of the mural, the Buddha sits in contemplation (Fig 10). He closes his eyes in search of awakening while raising a hand to repel the secular world. Buddha is tested with his patience and resolution and succeeds; he devotes himself to the Four Noble Truths that other disturbing thoughts can never afflict him. The rest of the mural is crowded with monsters, followers of the evil King Mara (Fig 11). They try to disturb him with their ferocious appearances and menacing movements. However, no monster has successfully assaulted the Buddha. By acquiring power from the Four Noble Truths, the Buddha transforms the three beauties on the left (Fig 12), who tried to allure him, into three old women (Fig 13). The old women observe their withering bodies with fear; they suffer under their desire for beautiful appearances and lust, which they can no longer fulfill.

The Buddha can ignore desires and continue his enlightenment painlessly. The artist(s) aroused the viewer's imagination: if the Buddha is not as sedate and resolute, will the monsters conquer him and relegate him to the cycle of pain? The precondition of Buddha's enlightenment is his inner peace—without visualization, viewers can still perceive its existence. The chaotic situation corresponds with the long-lasting tumult that precedes the Northern Wei dynasty; a Northern Wei Buddhist may learn from the Buddha that inner peace and meditation can evade their pain and exhaustion after the tumult.



Fig 14: Giotto di Bondone, *The Last Judgment*, 1306 AD. Scrovegni Chapel, Padua (Hurst).

Similar to *Mara's Defeat*, the Last Judgment is also a crucial Christian iconography, which visualizes humans' settlement in the afterlife. Christ will determine that some, who have done good in their lives, rise to heaven, and others, who have been evil in life, fall to hell and suffer endlessly.

The Scrovegni Chapel in Padua, Italy, more commonly known as the Arena Chapel, was consecrated in 1305. Its owner, Enrico Scrovegni (1267-1336 AD), commissioned the late medieval artist Giotto (c. 1266-1337 AD) for the fresco cycle in the chapel. Giotto placed *the Last Judgment*, a 10 x 8.4m fresco, on the entrance wall (Fig 14).



Fig 15-18: Details of *The Last Judgment* by Giotto (Zucker).

Christ sits in the center of the fresco, above the cross on which he was crucified. He is recognized by his enormous figure, the mandola, and the cruciform halo. He spreads his hands as

though he is weighing a person's qualities. The apostles line up along with him and watch the judgment; other angels hold flags and blow trumpets to celebrate doomsday.

On the bottom left, naked figures crawl out of their coffins (Fig 16). Their naked bodies reveal their qualities and deeds to Christ. Christ is to judge them and place them in heaven or hell. A crowd rises from the ground and waits for their judgment. They are the pious Christians who can rise to heaven: they are led by angels to their deserved destiny, and some pray for Christ's blessing. On the right side of the cross, hell occupies the same area as heaven (Fig 17). Red, the color of blood, and black, the color of darkness, contrast with the light colors in heaven. While blessed people levitate, damned people fall; while blessed people express joy and hope, damned people are terrified and sorrowful; while the blessed line up orderly, damned people form chaos, struggling with different punishments according to their sins. Satan continues his cruel killings: he grasps one person in each hand and swallows another.

When visitors return from the chapel to the secular world, they will come under the fresco. Heaven and hell are equally presented by the entrance. The fresco is an impartial showcase of Christian beliefs. By picturing heaven and hell in the same size but different colors and different extents of dynamism, Giotto reminds the visitors that the afterlife they will spend depends on how they behave in the secular world; the brutal scene of hell intimidates the viewers and warns them the consequences if they carry out sins.

Since the 14th century, kingdoms in Europe frequently waged war with each other. Wars disturbed societies and terrified people. Many conducted sins to live better—Enrico Scrovegni, for instance, created the Scrovegni Chapel to recompense for his sin of usury. To avoid upheavals, religious artworks depicting hell were produced, warning Christians that if they violated the religion's doctrines, they would suffer under greater violence and darkness after death. Giotto's Last Judgment also reflects Scrovegni's fear of hell as he deferentially dedicates the chapel to the three Marys, longing for heaven.

Both *Illustration of Mara's Defeat* and Giotto's *The Last Judgment* provide guidance on how believers can liberate themselves from suffering and lead virtuous lives. They also present factors that can lead individuals astray. They remain informative and instructive instead of imposing a sense of obligation upon believers. However, they implicitly evoke emotional and rational responses from the viewers through images of suffering: due to fear of suffering, viewers begin to introspect about their own behaviors. They are encouraged to exercise self-restraint and align themselves with religious teachings so that in their reincarnation or afterlife, they will no longer suffer.



### CASE 3

#### IDEAL LIVES AND SELF-EXPRESSION

---*Illustration of the Amitabha Sutra and Last Judgment by Michelangelo*



Fig 19: Anon artist(s), *Illustration of the Amitabha Sutra*, 642 AD. Mogao Grottoes, Dunhuang (遥远经典 近在眼前).

The *Illustration of the Amitabha Sutra* in Cave 220 dates to the Early Tang, mid 7<sup>th</sup> century (Fig 19). The *Amitabha Sutra* is a collection of Buddha's sayings about Sukhavati, the Western Pure Land. According to karma, Buddhists who perform extremely good deeds despite tremendous challenges can live in the Sukhavati in their next incarnation.

The mural introduces its viewers to Sukhavati: it centers the supreme Amitabha Buddha, while including lavish details, from figures to architecture, of this paradisiac Buddhist pure land.

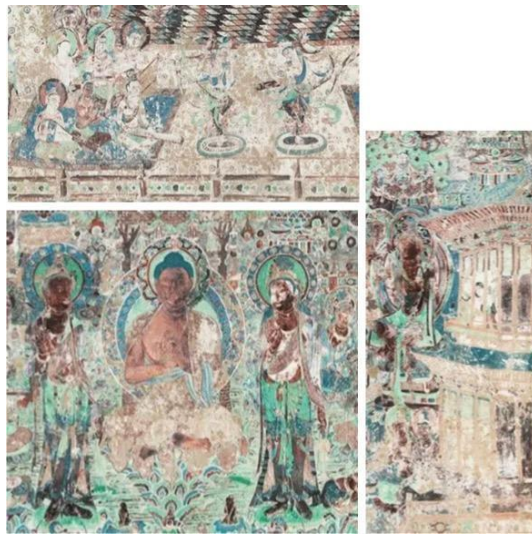


Fig 20-22: Details of *Illustration of the Amitabha Sutra*.

The absence of “suffering elements” in this mural is noteworthy. The Amitabha Buddha, sitting in the middle of a pond, watches the world in peace (Fig 20). His rounded silhouette and amiable temperament suggest both realism and Early Tang’s preference for physical health. Surrounding him is a huge crowd enjoying their entertaining life (Fig 21). They can join any activity to please themselves: some accompany the dancers by playing their instruments, some share their day with the Buddha, and others climb the pavilion to gaze at the hedonistic world. The instruments, the dancer’s costumes, and the architecture all reflected the secular society, which implies that the depiction of Sukhavati is not entirely imaginary but based on the burgeoning Tang society. In the Northern Wei dynasty, Buddhists could barely extricate from pain, let alone satisfy their desires; in the Early Tang, their realistic desires were satisfied, so they began considering the unrealistic, such as freeing themselves from suffering and living in eternal happiness. The loss of suffering in *Illustration of the Amitabha Sutra* also signified the change of Buddhism’s function: not to evoke or to teach, but to entertain its followers.



Fig 23: Michelangelo di Lodovico Buonarroti Simoni, *The Last Judgment*, 1535-1541 AD. Sistine Chapel, Vatican City (De Mendoza).

The similar issue in the Tang Buddhist art also appeared in its Renaissance counterpart.



The Sistine Chapel has been the papal chapel and the venue of the pope's election since the 16th century. In 1535, Michelangelo di Lodovico Buonarroti (1475-1564), who had painted the Sistine Chapel ceiling, was re-commissioned to paint its walls. *The Last Judgment* fresco (Fig 23), located on the altar wall, was heavily inlaid with Michelangelo's emotions, different from Giotto's impartial representation of heaven and hell.



Fig 24-25: Details of *The Last Judgment* by Michelangelo.

Light, which indicates heaven, comes from the top left. On the bottom right is the river to hell, the darkest area in the fresco. Between the illuminated and the shaded is Christ judging the multitude. There were intense fights between the escaping damned and the angels, but Michelangelo does not visualize hell and the punishments because the Sistine Chapel is meant to house the supreme and upright pope, who could not fall into hell in his afterlife; furthermore, to gain more Catholics, the fresco needed to propagandize the religion with bright or obscure images.

Michelangelo also humanized suffering and evoked the viewer's emotions. A damned man half-covers his face in despair and apprehension (Fig 24). He is unaware of his sins until the demon drags him toward the boat to hell. While his fear of hell and resistance to endless suffering was prominent, the viewers can deduce that he has not followed Christ during his lifetime and has been unaware of his sins. Through the damned man, Michelangelo suggests that one should realize the consequences of conducting sins and do good to avoid distress in the afterlife.

Surrounding Christ is a group of saints, gazing attentively at him and holding their

instruments of martyrdom. St. Bartholomew has his skin with his left hand, and the knife pierces it with his right hand (Fig 25). The skin, however, renders the face of Michelangelo himself. Replacing a saint's skin with a laity's would have been the sin of iconoclasm in the Middle Ages, but with the rise of humanism, society became more open-minded to the artists' choices. Michelangelo is woeful, his limbs of skin dangling from St. Bartholomew's hand. He can almost fall into the boat of hell. Though Michelangelo may fear hell like the damned man, he looks highly discouraged by life that he would accept being damned.

Due to both religions' need to attract a larger population, *Illustration of the Amitabha Sutra* and Michelangelo's *The Last Judgment* are affected by religious propaganda. Both artworks deliberately avoid images of violence and sacrifice. However, suffering is not completely absent from *The Last Judgment* because, during the Renaissance, the rise of humanism allowed more voices from the artists. Though there are compromises—religious images should adapt for the laity's favor—artists could visually interpret “suffering” based on their opinions.

## **Conclusion**

Suffering was an integral theme in religious art. Religion aimed for dissemination, while followers sought spiritual benefits. Suffering is an inescapable aspect of life, a flaw inherent in existence. Religion, being an adjunct to life, emphasizes utility to garner followers, particularly in times of conflict, when the issue of suffering is magnified. On the one hand, religions pragmatically addressed and instructed people on how to confront suffering; on the other, because images of suffering raised the viewers' empathy, the viewers would grow dependent on the religion, like their mental advisor. When religion serves political needs, the relationship becomes one where individuals must adhere to doctrines to gain benefits, rendering them passive.

People's desires were amplified and satisfied in more politically and socially stable times. Without the need for spiritual support, the imagery of suffering diminished. The dynamic between religion and individuals reversed: religion caters to human needs, and people become proactive, exemplifying the rise of humanism. Beyond utility, religion underscores its role in providing happiness and solace. The evolution of religious art paralleled the changes in eras: China and Europe transitioned from turbulent times to stable periods, reshaping artists' understanding of suffering similarly.

## Works Cited

- “Buddhism in China.” *Pew Research Center’s Religion & Public Life Project*, 6 Sept. 2023, <https://www.pewresearch.org/religion/2023/08/30/buddhism/>. Accessed 15 Sept. 2023.
- De Mendoza, Alonso. “File:Last Judgement (Michelangelo).jpg.” *Wikimedia Commons*, 21 Nov. 2015, [https://commons.wikimedia.org/wiki/File:Last\\_Judgement\\_\(Michelangelo\).jpg](https://commons.wikimedia.org/wiki/File:Last_Judgement_(Michelangelo).jpg).
- “East-West Schism | Summary, History, & Effects.” *Encyclopedia Britannica*, 28 May 2023, <https://www.britannica.com/event/East-West-Schism-1054>. Accessed 28 Aug. 2023.
- “Europe Main Map at the Beginning of the Year 1500.” *Euratlas*, <https://www.euratlas.net/history/europe/1500/index.html>. Accessed 27 Aug. 2023.
- Gibbon, Edward. “Chapter 2 of ‘The History Of The Decline And Fall Of The Roman Empire.’” *Christian Classic Ethereal Library*, <https://www.ccel.org/g/gibbon/decline/volume1/chap2.htm>. Accessed 29 Aug. 2023.
- Greene, Eric M. “The ‘Religion of Images’? Buddhist Image Worship in the Early Medieval Chinese Imagination.” *Journal of the American Oriental Society*, vol. 138, no. 3, 2018, pp. 455–84. <https://doi.org/10.7817/jameroriesoci.138.3.0455>.
- Hurst, Michael. “File:Last-judgment-scrovegni-chapel-giotto-1306.jpg.” *Wikimedia Commons*, 9 Jan. 2013, <https://commons.wikimedia.org/wiki/File:Last-judgment-scrovegni-chapel-giotto-1306.jpg>.
- “LibGuides: G8: Medieval Times: Social Structures.” *Libguides*, <https://acs-schools.libguides.com/c.php?g=688283&p=4926389>. Accessed 28 Aug. 2023.
- Lopez, Donald S. “Buddha | Biography, Teachings, Influence, & Facts.” *Encyclopedia Britannica*, 8 Aug. 2023, <https://www.britannica.com/biography/Buddha-founder-of-Buddhism>. Accessed 28 Aug. 2023.
- King, Martin Luther, Jr. “The Chief Characteristics and Doctrines of Mahayana Buddhism.” *The Martin Luther King, Jr. Research and Education Institute*, 28 Apr. 1950, <https://kinginstitute.stanford.edu/king-papers/documents/chief-characteristics-and-doctrines-mahayana-buddhism>. Accessed 28 Aug. 2023.
- “Mogao Caves.” *UNESCO World Heritage Centre*, <https://whc.unesco.org/en/list/440/>. Accessed 28 Aug. 2023.
- National Geographic Maps [@natgeomaps], “Map of Tang Dynasty (618-907 C.E.),” *Instagram*, 5 Mar. 2023, <https://www.instagram.com/p/CpX-W92v5Id/>. Accessed 29 Aug. 2023.
- “Pietro Lorenzetti | The Crucifixion.” n.d. *The Metropolitan Museum of Art*, <https://www.metmuseum.org/art/collection/search/438605>.
- “Shibi Jataka Illustration, Mural Painting.” n.d. *UW Dunhuang Project: Exhibitions*, <https://dunhuang.ds.lib.uw.edu/Dunhuang-Exhibitions/items/show/9>.
- SS. “Northern Wei Map.” *Wikimedia Commons*, 22 Dec. 2022, [https://commons.wikimedia.org/wiki/File:Northern\\_Wei\\_map.jpg](https://commons.wikimedia.org/wiki/File:Northern_Wei_map.jpg). Accessed 29 Aug. 2023.

- Steinhardt, Nancy Shatzman. "Interior of Mogao Cave 254, Gansu, Northern Wei." *JSTOR*, 2019, <https://doi.org/10.2307/j.ctvc77f7s.11>.
- Vermeersch, Sem. "Syncretism, Harmonization, and Mutual Appropriation between Buddhism and Confucianism in Pre-Joseon Korea." *Religions*, vol. 11, no. 5, 8 May 2020, p. 231, <https://doi.org/10.3390/rel11050231>. Accessed 29 Aug. 2023.
- Wang, Jixun. "北魏时期的崇佛热与佛教政治化现象研究: ——以‘中研院史语所’编北魏佛教拓片五十三品为例." *Theory Journal*, vol. 9, no. 223, Sept. 2012, pp. 97–100, <https://www.doc88.com/p-1991588748755.html>. Accessed 28 Aug. 2023.
- 遥远经典 近在眼前. "【神游千年, 大美敦煌】北魏-254窟【2】南壁+动画《降魔成道》(敦煌研究院出品)【高清大图】." *Zhihu*, 22 July 2019, <https://zhuoanlan.zhihu.com/p/74613424>.
- 遥远经典 近在眼前. "【神游千年, 大美敦煌】初唐-220窟“最美传奇窟”-南壁-阿弥陀经变: 净土宝池虚空, 佛菩萨济济一堂赏乐舞【高清大图】." *Zhihu*, 29 Apr. 2022, <https://zhuoanlan.zhihu.com/p/502112681>.
- Zucker, Steven. "Giotto, Last Judgment, detail with Enrico Scrovegni Presenting Chapel to the Three Marys, Arena Chapel." 10 Dec. 2019, *Flickr*, uploaded 2 Aug. 2020, <https://www.flickr.com/photos/profzucker/50181619598/in/photostream/>.

# The Treatment of Alzheimer's Disease Through Transplantation to the Hippocampus and Lateral Ventricles By Hudson Mar

## Abstract

Alzheimer's Disease (AD) is a memory loss disease, and a form of dementia. There are many speculations of what causes AD, but limited breakthroughs have made it difficult to form an official cause. There are several current treatments for AD, but one of the leading treatments is using stem cells specifically through stem cell transplantation. One of the main challenges with these injections is locating the target for therapy within the brain. There are several surgical targeting locations to inject stem cells into, including the amygdala, the lateral ventricles, and the hippocampus. This article reviews the pathology of AD while exploring the anatomical sites for stem cell injections.

## Introduction:

Dementia is a brain degenerative disease, causing cognitive decline and loss of function<sup>1</sup>. AD is responsible for around 65% of all dementia cases, affecting around 47 million people worldwide in 2017<sup>2</sup>. One of the main AD symptoms is shrinkage and weight loss of the brain as a result of neural and glial cell loss<sup>3</sup>. The brain is one of the most important, yet complex organs in the human body. It is located inside the cranium, or the skull. The brain is connected to the spinal cord, which makes up the central nervous system (CNS)<sup>4</sup>. Together, they are able to help us feel or process information through our six senses and perform everyday.

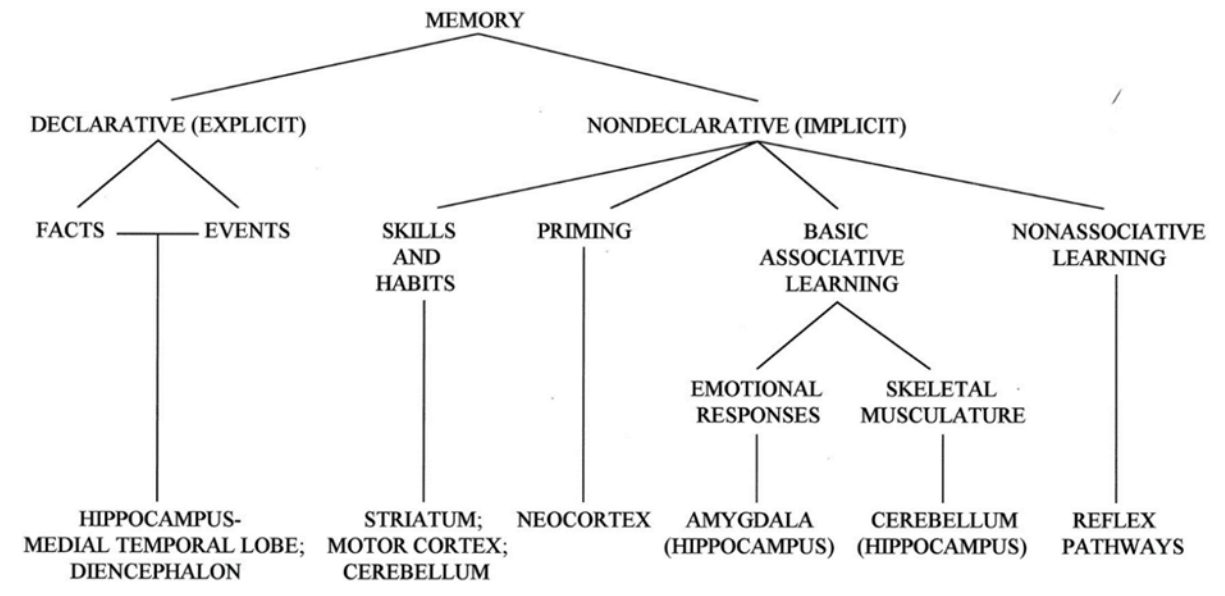


Figure 1: Obtained from Bartsch et. a. 2011<sup>5</sup>  
Schematic associating functions of memory with structures in the brain.

Many parts of the brain help contribute to memory. As shown in Figure 1, there are 2 different types of memory; declarative and nondeclarative. Declarative memory, responsible for the facts and events happening around us is held inside the hippocampus, specifically the medial temporal lobe. Nondeclarative memory, responsible for unconscious thoughts and everyday activities, is held in many locations including the amygdala, cerebellum, and neocortex<sup>5</sup>. AD affects both declarative and nondeclarative memory.

Currently, a cure or effective treatment for AD hasn't been developed. Researchers and scientists are focusing on the accumulation of amyloid beta plaques and neurofibrillary tangles (NFT) in the brain<sup>6</sup>. Amyloid beta plaques originate from a mutation in the APP gene. The mutation allows for an increase in A $\beta$  levels, eventually results in neurotoxicity<sup>7</sup>. NFTs are created through the overproduction of the hyperphosphorylated tau protein. Similarly, to A $\beta$ , this is caused by certain gene mutations<sup>8</sup>. While A $\beta$  plaques hinder the nervous system's ability to communicate, the tau protein shrinks or kills cells in the brain. Neurons in the CA1, CA2, CA3, and CA4 area are all affected, but neurons residing in the CA1 area are impacted the most<sup>3</sup>. Stem cell-based therapies have been explored to treat AD<sup>1-27</sup>.

Stem cells can be found throughout the entire human body. There are many different types of stem cells however neural stem cells are the most helpful for battling AD. Neural Stem Cells, or NSCs, are found in the adult brain, specifically the hippocampus and lateral ventricles where neurogenesis occurs<sup>9</sup>. While NSCs can transform into neurons and astrocytes, as well as other CNS cells, they are restricted to cells of the CNS and thus classified as multipotent. There are 2 lateral ventricles in the brain, both of which are found in the cerebellum. They are C-shaped structures which reach into the frontal, temporal, and occipital lobes. They act as storage vessels filled with cerebrospinal fluid (CSF). Each ventricle can hold up to 7-10mL of CSF. CSF has been found to contain neural stem cells, providing an opening to treat neurodegenerative diseases<sup>10</sup>.

As shown in table 1, there are several types of stems that could help fight AD; however, only neural stem cells are currently being used to help treat AD. They can help build neurons which AD, potentially restoring damaged signal pathways. While they are in many parts of the brain, they can also be transplanted as a potential treatment for AD.

Table 1: Adapted from Vasic et. al. 2019<sup>11</sup>  
Classes of stem cells with corresponding advantages and disadvantages.

<b>Stem Cells</b>	<b>Advantages</b>	<b>Disadvantages</b>
Embryonic stem cells (ESCs)	Pluripotent, self-renewal	Unethical, uncontrollable
Neural stem cells (NSCs)	Multipotent	Poor survival



Induced-pluripotent stem cells (iPSCs)	Pluripotent	Possibly cancerous, abnormal cell growth
Mesenchymal stem cells (MSCs)	Multipotent	Slow neuronal differentiation

### Stem Cell Transplantation

Stem Cells Transplantation is an increasingly popular treatment for AD. However, because there has been minimal success in clinical trials, stem cell transplantation has not moved forward into clinical practice. Stem cell transplantation can be very efficient and effective because stem cells can be placed directly in the targeted area. However, there are a lot of concerns and unknowns such as, how much solution to inject, where to inject, and what type of stem cells to inject. There are many possible stem cells that can be injected such as embryonic stem cells (ESCs), mesenchymal stem cells (MSCs), or induced pluripotent stem cells (iPSCs), however, neural stem cells (NSCs) can specifically help with generating all different neurons to support the hippocampus and lateral ventricle in building more neurons. Furthermore, NSC transplantation has found the most success in rodent trials. Although there has been a lot of success in animal trials, that success hasn't transferred over to human trials. Despite an increase in the amount of trials since 2002, there has been a lot of difficulty in finding success with human trials (99.6% failure rate) and getting to Phase 3 in trials (20%)<sup>12</sup>.

### AD Pathology–A $\beta$ protein

A $\beta$  is commonly associated with AD. In 1985, amyloid fibrils containing amyloid  $\beta$  were found in the senile plaque which was one of the two abnormal structures associated with AD <sup>13</sup>. While there hasn't been any concrete evidence proving a direct correlation between A $\beta$  levels and AD, an increase in A $\beta$  resulting in AD remains one of the leading theories. These levels are increased through the process of A $\beta$  aggregation. A $\beta$  aggregation has been associated with mutations in PSEN 1, PSEN 2, APP, trisomy 21, and or a third copy of APP <sup>14</sup>. Recent studies concluded that A $\beta$  aggregation leads to the production of insoluble oligomeric conformations of A $\beta$ . These oligomers can be neurotoxic, causing neuronal damage and, possibly, AD <sup>15-16</sup>. A $\beta$  filaments are mostly found in the hippocampus, amygdala, or cerebral cortex. One possible correlation to a rise of A $\beta$  levels is related to a genetic disease, Down's syndrome. People with Down's syndrome develop amyloid beta plaques proteins while growing up, which is associated with the development of AD later in their life <sup>17</sup>.  $\beta$ -amyloid precursor protein ( $\beta$ APP) is associated with the development of AD in Down's syndrome patients. An excessive production of APP, specifically through the process of phosphorylation, can lead to production of the A $\beta$  plaque protein. However, a removal of APP, can lead to behavioral problems and restrictions in muscle movement. Additionally, APP isn't the only process of producing  $\beta$ -amyloid proteins, a genetic mutation, ApoE4 polymorphism, has been identified as a genetic risk factor which

heavily increases A $\beta$  protein levels. Mutations in presenilin genes can also increase the production of A $\beta_{42}$  peptides which increase A $\beta$  plaque<sup>18</sup>.

## Tau

Another characteristic related to AD are neurofibrillary tangles (NFT), which similarly to senile plaques, contain a protein. Hyperphosphorylated tau proteins create pair helical filaments (PHF), which are a main component for NFTs. Tau protein kinases I and II result in the hyperphosphorylation of tau<sup>19</sup>. Others believe the tau hypothesis is the reason behind AD. The main points behind the hypothesis are that due to A $\beta$  increase, Tau becomes over phosphorylated, especially in locations near microtubules, eventually dissociating with microtubules and creating NFTs in the neurons which leads to AD. The presence of NFTs causes neuronal dysfunction and cell death. This loss of neurons is heavily associated with neurodegenerative diseases such as AD<sup>20</sup>.

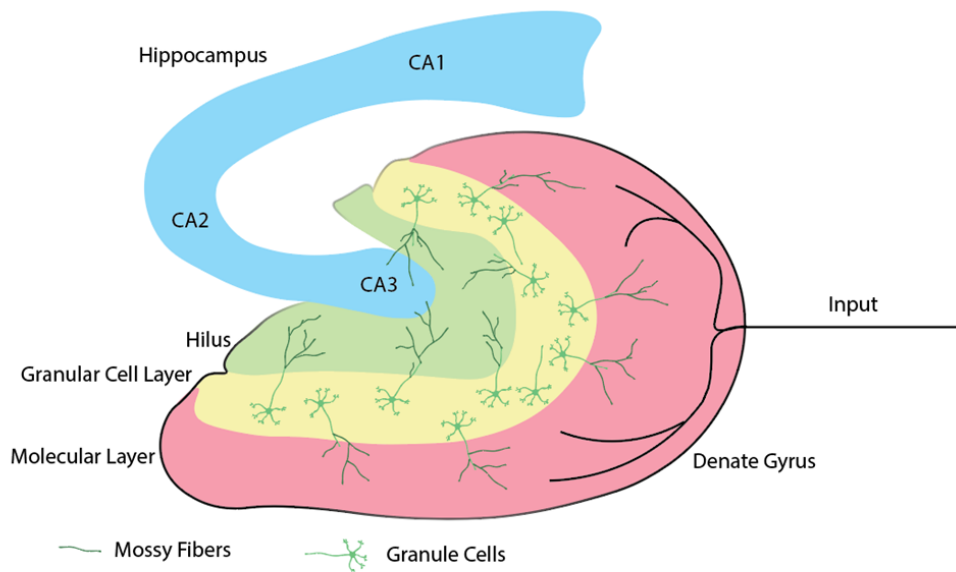


Figure 2: Obtained from (Selkoe, 1996)<sup>21</sup>

Location and migration pathway of neural stem cells (neural progenitor cells) in the Hippocampus.

## Sites for Injection–Hippocampus

One of the popular investigational approaches to fighting AD is transplanting stem cells into the hippocampus. While there is a lot unknown about AD, scientists have discovered the hippocampus is heavily involved in the early stages of AD. The hippocampus naturally contains neural stem cells, specifically located in the granular layer of the dentate gyrus. However, in AD, millions of neurons are lost in this area, specifically CA1 neurons, which help with self-identity,

self-awareness, or facts about their past (ex: birthday)<sup>5</sup>. However, while this cell death leads to hippocampal neurogenesis, which creates neurons, those neurons don't serve the same function. As a result, the new neuron fails to fully replace the function of the lost neurons. Thus, the progression of AD continues to lead to further cell death. Researchers hypothesize that to help with the loss of neurons, stem cells can be transplanted into this area. Using human neural stem cells, mice with AD can restore their recognition, learning, and memory ability when transplanted into the bilateral hippocampal CA1 region. Additionally, nerve density significantly increased leading to an increase in brain metabolic activity. Amyloid beta levels and amyloid beta plaques didn't significantly decrease; however, there was a significant restoration in cognitive function <sup>22</sup>.

Recent scientific studies have found senile plaques, whose main components are amyloid- $\beta$  proteins<sup>23</sup>, are created following abnormal production of tau and formation of NFTs. This is fascinating because it was assumed NFTs were a result of A $\beta$  production. This creates the possibility of an increase of A $\beta$  levels as a result of NFTs. While scientists have not been able to prove a direct correlation between A $\beta$  and tau, this discovery suggests a different possibility. Others have recently found that senile plaques are formed after the creation of neurofibrillary tangles. This challenged the previous notion, as it was assumed that NFTs were a result of A $\beta$  production <sup>24</sup>. This creates the possibility of A $\beta$  levels being a product of increased tau levels. Furthermore, it suggests a direct correlation between senile plaques and NFTs.

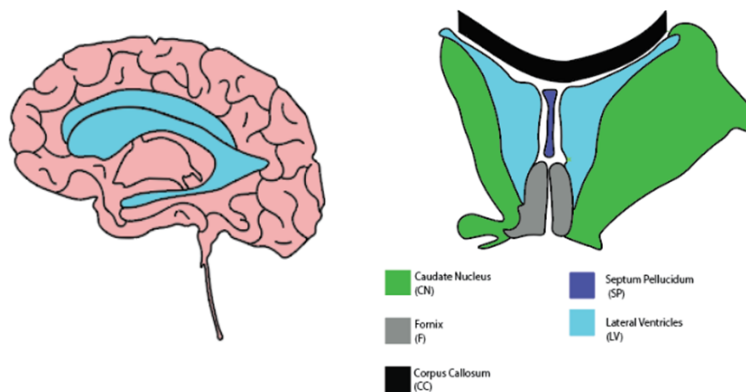


Figure 3:

Coronal cross-section of a brain showing the lateral ventricles bounded by the corpus callosum (CC) superiorly, septum pellucidum (SP) medially, fornix (F) inferiorly, and caudate nucleus (CN) laterally. Obtained from <sup>25</sup>

## Lateral Ventricle

The lateral ventricles are located in between the corpus callosum (CC), septum pellucidum (SP), fornix (F), and caudate nucleus (CN) inside the brain. They are 7-10mL horn-shaped storage vessels containing cerebrospinal fluid (CSF) <sup>25</sup>. In AD patients, this CSF contains A $\beta$  proteins, which is one of the pathological hallmarks for AD <sup>26</sup>. Scientists have found that the lateral ventricle enlarges naturally, however AD carriers tend to have larger ventricles due to neural atrophy <sup>27</sup>. Similarly to the hippocampus, the lateral ventricle is a location where neurogenesis occurs. However, as age increases, the rate of neurogenesis is reduced. Through the use of rodent trials, it has been found transplanting NSCs into the lateral ventricles of mice has led to a decrease in A $\beta$  levels and tau phosphorylation levels. This has also led to an increase in neuronal and nerve fiber density. While the mice were able to experience a restoration in recognition, learning, and memory, human trials have not been as successful.

Study Name	First Posted	Last Update	Recruiting Stage & Age Requirements/Enrollment	Location	Design	Result/Primary Outcome Measures
GV1011 Subcutaneous (SC) for the Treatment of Mild to Moderate Alzheimer's Disease	January 12, 2022	November 23, 2022	Recruiting (55-85, 180)	United States, Florida	Using GV1011 to protect Neural Stem Cells in the brain	Improve off baseline ADAS-Cog 11 score by Week 52
PMZ-1620 (Sovateptide) in Mild to Moderate Alzheimer's Disease	August 12, 2019	January 12, 2023	Completed (45-85, 180)	Chandigarh, India Lucknow, India Mumbai, India New Delhi, India	Use PMZ-1620 to boost ability of hidden stem cells	Find the negative effects and tolerance of PMZ while looking at changes in AD progression

Reprogramming myeloid cell metabolism to prevent cognitive aging and Alzheimer's Disease	March 1, 2021		United States, California	Does myeloid deficits drive brain aging, does targeting myeloid metabolism treat AD.
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## Discussion

Stem cell therapy has shown a lot of promise to treat AD. A direct transplantation of stem cells seems like an effective treatment as it's been used successfully against other complex diseases like AD. Stem cells have the potential to create neurodegenerative medicine. The use of neural stem cells has already been proven effective when used in animal trials. Further stem cell therapy trials could provide evidence to solidify a cause to AD. Additionally, there's a possibility AD could be a genetic disease, as it could be associated with Down's Syndrome. Research towards the effectiveness of gene therapy could become useful. Lastly, research targeting specific environmental factors that could play a role in the development of AD could also be useful.

Despite overall advancements in stem cell therapy, especially in animal trials, there are many dangers of this type of treatment. It's best if we continue to research and advance cautiously, as we currently don't know the full functionality and potential of stem cells. Furthermore, a lack of concrete evidence to support the amyloid or tau hypothesis has made it difficult for research advancements.

Because of limited research on stem cells, there are a lot of unknowns. There could be many possible problems with stem cells such as the use of embryonic stem cells. Furthermore, there could be possible problems with stem cells multiplying and becoming cancer cells. Limited human trials could be due to fear of possible results. Stem Cells are a relatively new source of medicine, therefore, with limited research, patients may be hesitant to give their body to an unknown part of science. Regardless of current success in stem cell therapy, there are many remaining questions.

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## Works Cited

- Thompson, R. F.; Kim, J. J. Memory Systems in the Brain and Localization of a Memory. *Proc. Natl. Acad. Sci.* **1996**, *93* (24), 13438–13444. <https://doi.org/10.1073/pnas.93.24.13438>.
- World Health Organization. *Global Action Plan on the Public Health Response to Dementia 2017–2025*; World Health Organization: Geneva, 2017.
- Sengoku, R. Aging and Alzheimer's Disease Pathology. *Neuropathology* **2020**, *40* (1), 22–29. <https://doi.org/10.1111/neup.12626>.
- Bolon, B.; Garman, R. H.; Pardo, I. D.; Jensen, K.; Sills, R. C.; Roulois, A.; Radovsky, A.; Bradley, A.; Andrews-Jones, L.; Butt, M.; Gumprecht, L. STP Position Paper: Recommended Practices for Sampling and Processing the Nervous System (Brain, Spinal Cord, Nerve, and Eye) during Nonclinical General Toxicity Studies. *Toxicol. Pathol.* **2013**, *41* (7), 1028–1048. <https://doi.org/10.1177/0192623312474865>.
- Bartsch, T.; Döhring, J.; Rohr, A.; Jansen, O.; Deuschl, G. CA1 Neurons in the Human Hippocampus Are Critical for Autobiographical Memory, Mental Time Travel, and Auto-noetic Consciousness. *Proc. Natl. Acad. Sci.* **2011**, *108* (42), 17562–17567. <https://doi.org/10.1073/pnas.1110266108>.
- Ittner, L. M.; Götz, J. Amyloid- $\beta$  and Tau — a Toxic Pas de Deux in Alzheimer's Disease. *Nat. Rev. Neurosci.* **2011**, *12* (2), 67–72. <https://doi.org/10.1038/nrn2967>.
- Sadigh-Eteghad, S.; Sabermarouf, B.; Majdi, A.; Talebi, M.; Farhoudi, M.; Mahmoudi, J. Amyloid-Beta: A Crucial Factor in Alzheimer's Disease. *Med. Princ. Pract.* **2015**, *24* (1), 1–10. <https://doi.org/10.1159/000369101>.
- Binder, L. I.; Guillozet-Bongaarts, A. L.; Garcia-Sierra, F.; Berry, R. W. Tau, Tangles, and Alzheimer's Disease. *Biochim. Biophys. Acta BBA - Mol. Basis Dis.* **2005**, *1739* (2–3), 216–223. <https://doi.org/10.1016/j.bbadis.2004.08.014>.
- Duan, X.; Kang, E.; Liu, C. Y.; Ming, G.; Song, H. Development of Neural Stem Cell in the Adult Brain. *Curr. Opin. Neurobiol.* **2008**, *18* (1), 108–115. <https://doi.org/10.1016/j.conb.2008.04.001>.
- Ren, C.; Yin, P.; Ren, N.; Wang, Z.; Wang, J.; Zhang, C.; Ge, W.; Geng, D.; Wang, X. Cerebrospinal Fluid-Stem Cell Interactions May Pave the Path for Cell-Based Therapy in Neurological Diseases. *Stem Cell Res. Ther.* **2018**, *9* (1), 66. <https://doi.org/10.1186/s13287-018-0807-3>.
- Vasic, V.; Barth, K.; Schmidt, M. H. H. Neurodegeneration and Neuro-Regeneration—Alzheimer's Disease and Stem Cell Therapy. *Int. J. Mol. Sci.* **2019**, *20* (17), 4272. <https://doi.org/10.3390/ijms20174272>.
- Cummings, J. L.; Morstorf, T.; Zhong, K. Alzheimer's Disease Drug-Development Pipeline: Few Candidates, Frequent Failures. *Alzheimers Res. Ther.* **2014**, *6* (4), 37. <https://doi.org/10.1186/alzrt269>.
- Masters, C. L.; Simms, G.; Weinman, N. A.; Multhaup, G.; McDonald, B. L.; Beyreuther, K. Amyloid Plaque Core Protein in Alzheimer Disease and Down Syndrome. *Proc. Natl. Acad. Sci.* **1985**, *82* (12), 4245–4249. <https://doi.org/10.1073/pnas.82.12.4245>.

- Morris, G. P.; Clark, I. A.; Vissel, B. Inconsistencies and Controversies Surrounding the Amyloid Hypothesis of Alzheimer's Disease. **2014**.
- Broersen, K.; Rousseau, F.; Schymkowitz, J. The Culprit behind Amyloid Beta Peptide Related Neurotoxicity in Alzheimer's Disease: Oligomer Size or Conformation? *Alzheimers Res. Ther.* **2010**, *2* (4), 12. <https://doi.org/10.1186/alzrt36>.
- Lambert, M. P.; Barlow, A. K.; Chromy, B. A.; Edwards, C.; Freed, R.; Liosatos, M.; Morgan, T. E.; Rozovsky, I.; Trommer, B.; Viola, K. L.; Wals, P.; Zhang, C.; Finch, C. E.; Krafft, G. A.; Klein, W. L. Diffusible, Nonfibrillar Ligands Derived from A $\beta$ <sub>1-42</sub> Are Potent Central Nervous System Neurotoxins. *Proc. Natl. Acad. Sci.* **1998**, *95* (11), 6448–6453. <https://doi.org/10.1073/pnas.95.11.6448>.
- Selkoe, D. J. Amyloid  $\beta$ -Protein and the Genetics of Alzheimer's Disease. *J. Biol. Chem.* **1996**, *271* (31), 18295–18298. <https://doi.org/10.1074/jbc.271.31.18295>.
- Zheng, H.; Koo, E. H. The Amyloid Precursor Protein: Beyond Amyloid. *Mol. Neurodegener.* **2006**, *1* (1), 5. <https://doi.org/10.1186/1750-1326-1-5>.
- Imahori, K.; Uchida, T. Physiology and Pathology of Tau Protein Kinases in Relation to Alzheimer's Disease. **1996**, 10.
- Mondragón-Rodríguez, S.; Salgado-Burgos, H.; Peña-Ortega, F. Circuitry and Synaptic Dysfunction in Alzheimer's Disease: A New Tau Hypothesis. *Neural Plast.* **2020**, *2020*, 1–11. <https://doi.org/10.1155/2020/2960343>.
- Kino, T. Stress, Glucocorticoid Hormones, and Hippocampal Neural Progenitor Cells: Implications to Mood Disorders. *Front. Physiol.* **2015**, *6*. <https://doi.org/10.3389/fphys.2015.00230>.
- Li, X.; Zhu, H.; Sun, X.; Zuo, F.; Lei, J.; Wang, Z.; Bao, X.; Wang, R. Human Neural Stem Cell Transplantation Rescues Cognitive Defects in APP/PS1 Model of Alzheimer's Disease by Enhancing Neuronal Connectivity and Metabolic Activity. *Front. Aging Neurosci.* **2016**, *8*. <https://doi.org/10.3389/fnagi.2016.00282>.
- Arai, H.; Lee, V. M.; Otvos, L.; Greenberg, B. D.; Lowery, D. E.; Sharma, S. K.; Schmidt, M. L.; Trojanowski, J. Q. Defined Neurofilament, Tau, and Beta-Amyloid Precursor Protein Epitopes Distinguish Alzheimer from Non-Alzheimer Senile Plaques. *Proc. Natl. Acad. Sci.* **1990**, *87* (6), 2249–2253. <https://doi.org/10.1073/pnas.87.6.2249>.
- Funato, H.; Enya, M.; Yoshimura, M.; Morishima-Kawashima, M.; Ihara, Y. Presence of Sodium Dodecyl Sulfate-Stable Amyloid  $\beta$ -Protein Dimers in the Hippocampus CA1 Not Exhibiting Neurofibrillary Tangle Formation. *Am. J. Pathol.* **1999**, *155* (1), 23–28. [https://doi.org/10.1016/S0002-9440\(10\)65094-8](https://doi.org/10.1016/S0002-9440(10)65094-8).
- Scelsi, C. L.; Rahim, T. A.; Morris, J. A.; Kramer, G. J.; Gilbert, B. C.; Forseen, S. E. The Lateral Ventricles: A Detailed Review of Anatomy, Development, and Anatomic Variations. *Am. J. Neuroradiol.* **2020**, *41* (4), 566–572. <https://doi.org/10.3174/ajnr.A6456>.

- Hu, X.; Crick, S. L.; Bu, G.; Frieden, C.; Pappu, R. V.; Lee, J.-M. Amyloid Seeds Formed by Cellular Uptake, Concentration, and Aggregation of the Amyloid-Beta Peptide. *Proc. Natl. Acad. Sci.* **2009**, *106* (48), 20324–20329. <https://doi.org/10.1073/pnas.0911281106>.
- Apostolova, L. G.; Green, A. E.; Babakchanian, S.; Hwang, K. S.; Chou, Y.-Y.; Toga, A. W.; Thompson, P. M. Hippocampal Atrophy and Ventricular Enlargement in Normal Aging, Mild Cognitive Impairment (MCI), and Alzheimer Disease. *Alzheimer Dis. Assoc. Disord.* **2012**, *26* (1), 17–27. <https://doi.org/10.1097/WAD.0b013e3182163b62>.



# **Illuminating the Dark Skies: A Study of Light Pollution and Its Impacts in Jammu and Kashmir, India By Taranpreet Singh**

## **Abstract**

The celestial spectacle that unfolds across the night sky, captivating generations with its timeless beauty, now faces a looming threat: light pollution. The relentless expansion of artificial nighttime illumination disrupts the harmonious relationship between the cosmos and our terrestrial realm. Light pollution, as recognized by organizations like the International Dark-Sky Association, transcends mere inconvenience to become a substantial challenge to our shared cultural and natural heritage. It fundamentally diminishes our ability to explore and understand the universe.

Beyond obscuring stars, light pollution impacts various domains, disrupting wildlife behavior, human sleep patterns, compromising health, and increasing energy consumption. Excessive artificial lighting scatters photons, leading to "skyglow," obscuring celestial wonders and affecting natural behaviors of species relying on light cues. Moreover, it disrupts human circadian rhythms, causing sleep disorders and negatively affecting health. Inefficient outdoor lighting contributes to energy waste and greenhouse gas emissions. Stargazers and astronomers, in particular, are affected by light pollution. Artificial light invades once-dark skies, obscuring cosmic wonders. Stargazing fuels curiosity and inspires thinkers worldwide.

## **Introduction**

The mesmerizing choreography of celestial objects across the night sky has been a wellspring of solace and inspiration for countless generations, a timeless spectacle that now stands under the imminent threat of our own creation: light pollution. The relentless expansion of artificial nighttime illumination disrupts the once-harmonious relationship between the cosmos and our terrestrial domain. As underscored in reports from esteemed organizations like the International Dark-Sky Association, light pollution transcends mere inconvenience; it emerges as a substantial challenge to the safeguarding of our shared cultural and natural legacy, fundamentally diminishing our capacity to explore and comprehend the universe.

Light pollution has evolved from a mere inconvenience to a global issue with far-reaching consequences. It is not just a matter of obscuring the stars; its impact extends to various domains, from disrupting wildlife behavior and human sleep patterns to compromising human health and increasing energy consumption (Chepesiuk, Ron). The intrusion of artificial light into the night sky scatters photons and creates a phenomenon known as "skyglow." (Longcore et al.) This not only obscures our view of celestial wonders but also affects the natural behaviors of many species, including birds, insects, and sea turtles, which rely on natural light cues for navigation and reproduction. Furthermore, excessive artificial lighting can disrupt human circadian rhythms, leading to sleep disorders and negatively affecting overall health. The inefficient and often excessive use of outdoor lighting contributes

to energy waste and increased greenhouse gas emissions.

While the global impact of light pollution is substantial, it is those who seek to explore the cosmos who are most affected. Stargazers and astronomers find their once-dark skies invaded by artificial light, rendering cosmic wonders hazy and elusive. This loss goes beyond simple inconvenience; it has profound implications. Stargazing not only fuels the curiosity of astronomers but also inspires dreamers and thinkers across the world.

Recognizing the growing importance of preserving access to unpolluted night skies, this research hones its focus on the remarkable region of Jammu and Kashmir, India. Nestled amidst the northern reaches of the country, this union territory is often referred to as the "Paradise on Earth" (Ankita Sharma et al.). Its resplendent landscapes, compelling topography, and remarkable biodiversity have long drawn admirers and explorers. With snow-capped peaks, pristine valleys, and serene lakes, it is a testament to nature's grandeur. Yet, there is another facet to this natural paradise that is lesser-known and often concealed.

As the sun dips below the horizon, a celestial spectacle unfurls over this enchanting land. The stark contrast between the inky, unblemished skies and the radiance of the stars is, perhaps, the region's best-kept secret. It conceals the vast beauty of the cosmos from those who have not yet ventured here. The union territory of Jammu and Kashmir stands as a shining gem, known for its unique blend of natural splendor and night skies that have enthralled stargazers for centuries. The pristine landscapes of the region, from the remote villages in the valleys to the snow-covered highlands, create an ideal canvas for stargazing.

Although the northern parts of Jammu and Kashmir still offer relatively better stargazing conditions compared to urban areas, light pollution is a growing concern in the region. The spread of artificial lighting, including streetlights and other sources, has begun to encroach upon even these pristine landscapes. While it may not be as severe as in bustling urban centers, it poses a significant threat to the pristine night skies that have long been a hallmark of this region. This encroachment has the potential to disrupt the clarity and brilliance of celestial objects and, consequently, the stargazing experience.

This research seeks to delve into the multifaceted challenge of light pollution and its impact on the stargazing experiences of the residents in the enchanting areas of Ranbir Singh Pura, Miran Sahib, and Vijaypur. Through an extensive survey, it aims to gain insight into the general public's perception of light pollution and its consequences. Additionally, a series of observational sessions were planned to gather scientific data on light pollution levels and their correlation with stargazing experiences. This holistic approach will not only help in raising awareness but also in establishing a scientific foundation for future policy measures aimed at preserving the pristine skies over Jammu and Kashmir.

## **Literature Review**

The enchanting landscapes of Jammu and Kashmir have historically offered an unparalleled celestial canvas, attracting stargazers from across the globe. However, the region's natural beauty, often revered as the "Paradise on Earth," has not remained untouched by the

spread of artificial light. Recent developments indicate a growing concern as urbanization advances, and artificial lighting encroaches upon this once-pristine territory. A significant instance of this transformation was marked in May 2021 when the Government of India sanctioned the installation of 19,000 solar streetlights in Jammu and Kashmir ("Govt sanctions 19,000 solar street lights for Jammu and Kashmir"). While this step was laudable as part of a broader move towards sustainable illumination, it brought to light the pressing issue of light pollution within the region. The installment of these streetlights followed the introduction of thousands of other artificial lighting sources, estimated at approximately 15,000 streetlights in the vicinity of the study regions, as provided by local authorities and informants. This increasing urban development and corresponding infrastructure change in the region's proximity are indicative of the significant challenge faced by stargazers and astronomers seeking to explore the skies above. These lighting interventions, while essential for urban development and safety, have the potential to disrupt the pristine skies that have long defined the region. However, this phenomenon has not yet been comprehensively studied within the specific context of Jammu and Kashmir. Therefore, this research seeks to bridge the gap and address the lack of dedicated academic exploration into the implications of light pollution on stargazing in this culturally significant territory.

### **Methodology–Observations**

**Location and Dates:** The observational phase of this study took place in the regions of Jammu District, specifically in the localities of Ranbir Singh Pura, Miran Sahib, and Vijaypur. The data collection spanned 12 days, from late June to late July in 2023, when celestial observations could best capture the unique conditions of the night sky.

**Instrumentation:** Multiple essential instruments were meticulously employed to measure and record critical factors that could significantly influence the quality of stargazing experiences. Two hygrometers were utilized to provide humidity measurements as a percentage, capturing prevailing moisture content in the atmosphere. Additionally, a handheld lux meter was employed to quantify the level of illumination, measuring illuminance in lux ( $\text{lm}/\text{m}^2$ ) (Mander, Susan, et al). Furthermore, the lunar phase was documented as a percentage, shedding light on how much of the moon's visible surface was illuminated. This information proved indispensable in understanding the potential impact of lunar phases on stargazing conditions.

**Sky Quality Meter (SQM):** The study employed a Dark Sky Meter, specifically the Sky Quality Meter (SQM), a handheld device designed to measure night sky brightness in magnitudes per square arcsecond ( $\text{mag}/\text{arcsec}^2$ ) (Mander, Susan, et al). This instrument provided a quantitative assessment of light pollution in the observation areas. The SQM reading is a comprehensive metric influenced by both artificial light pollution and natural sky brightness. To calculate magnitude per square arcsecond, the following formula was applied:

$$SQM = -2.5 \times \log_{10}(I/I_0)$$

The above formula calculates the Sky Quality Meter (SQM) reading, where:

- $SQM$  represents the Sky Quality Meter reading.
- $I$  denotes observed sky brightness.
- $I_0$  serves as the reference sky brightness.

**Naked Eye Limiting Magnitude (NELM):** The Naked Eye Limiting Magnitude

(NELM) is an imperative measure indicating the faintest stars visible to the naked eye under specific sky conditions. It serves as a fundamental criterion for evaluating the quality of the sky in observing celestial objects. The NELM for each observation day was not calculated but instead acquired through reliable online sources. One commonly utilized website for determining NELM values is 'Cleardarksky.com,' which offers NELM values for specific locations and dates, furnishing insights into the quality of the observable night sky. In addition, for the identification of celestial objects, a printed copy of Sky Atlas was used (Figure 1).

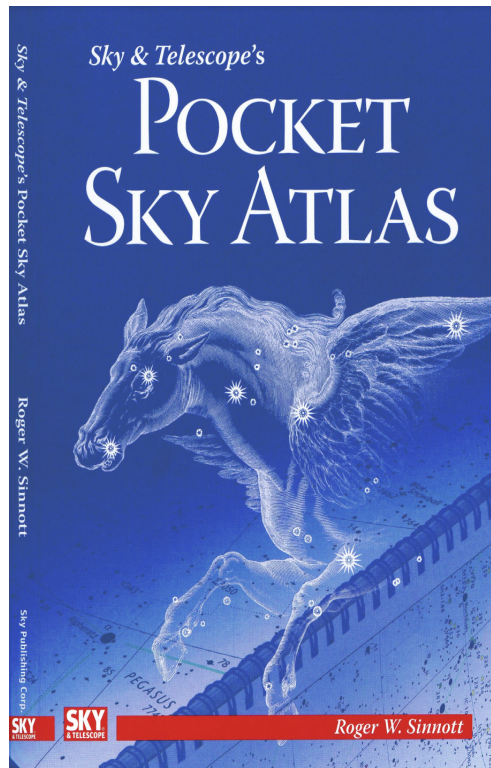


Figure 1: Sky and Telescope's 'Pocket Sky Atlas'

**Data Collection:** Over the course of the 12 observation days, a meticulous record was maintained, encompassing several crucial data points. These data points included Date, SQM (measured in mag/arcsec<sup>2</sup>), NELM, Lux (lm/m<sup>2</sup>), Moon Phase (%), Humidity (%), and Cloud Cover (%). The data procured during these observations laid the foundation for subsequent

analysis.

**Data Analysis:** The collected data underwent a thorough analysis, aimed at uncovering patterns, relationships, and trends. Line graphs were meticulously constructed and correlations were calculated to visually represent the variations in the key parameters, including SQM, NELM, Lux, Moon Phase, Humidity, and Cloud Cover, over the observation period. This data analysis visually conveys the influence of artificial lighting, lunar phases, and environmental conditions on stargazing experiences in the specified regions.

Date	SQM	NELM	Lux (lm/m <sup>2</sup> )	Moon Phase (%)	Humidity (%)	Cloud Cover (%)
28/06/2023	18.45	4.45	0.15	70.3	63	20
29/06/2023	18.33	3.2	0.2	79.4	76	7
30/06/2023	18.56	3.8	0.15	87.4	78	2
01/07/2023	18.32	3.2	0.19	93.9	64	10
06/07/2023	18.8	4.8	0.09	87.7	66	40
09/07/2023	18.87	4.2	0.11	57.7	62	20
10/07/2023	19.26	5	0.08	46.7	69	5
11/07/2023	18.34	3.2	0.13	36	65	10
13/07/2023	18.76	3.8	0.11	17.8	72	30
20/07/2023	19.03	4.2	0.1	6.3	80	30
21/07/2023	18.94	3.8	0.13	11.6	73	40
23/07/2023	18.86	3.86	0.12	26.2	70	10

Figure 2: Observational Data for Stargazing Condition

## Survey Methodology

**Awareness Campaign:** Before conducting the survey, an awareness campaign was carried out to introduce the participants to the concept of light pollution. This campaign included informational sessions and educational materials to ensure that the participants had a basic understanding of light pollution and its potential effects on stargazing and overall quality of life. The goal of this campaign was to ensure that respondents could meaningfully answer the survey questions related to light pollution.

**Survey Distribution:** The survey questionnaire, titled "Public Perceptions and Awareness of Light Pollution," was designed to gather information on participants' knowledge, perceptions, and concerns about light pollution. The questionnaire consisted of ten questions covering various aspects of light pollution awareness and its impacts. These questions were designed to assess the participants' stargazing habits, familiarity with the term "light pollution," their beliefs about how light pollution affects stargazing, their level of concern regarding light pollution, and their willingness to learn more about the issue. Additionally, the survey aimed to understand participants' knowledge of the negative impacts of light pollution on human health, their opinion on preserving dark skies for future generations, their likelihood of supporting initiatives to reduce light pollution, and their beliefs about how reducing light pollution could enhance celestial visibility and astronomical research.

**Participant Demographics:** The survey also collected demographic information to understand how responses might vary based on factors such as age, gender, educational attainment, and occupation. The demographic questions included age, gender, and educational attainment. Educational attainment was categorized into several levels, from less than high school to Doctorate/Ph.D. Furthermore, participants were asked to provide their occupation.

### Survey Questions:

- On a scale of 1 to 5, how often do you stargaze or observe the night sky?
- On a scale of 1 to 5, how familiar are you with the term "light pollution"?
- On a scale of 1 to 5, how much do you believe light pollution affects your ability to see stars and celestial objects?
- On a scale of 1 to 5, how concerned are you about the increasing levels of light pollution?
- On a scale of 1 to 5, how much do you believe light pollution affects the overall quality of life in urban areas?
- On a scale of 1 to 5, how interested would you be in learning more about the impacts of light pollution and ways to reduce it?
- On a scale of 1 to 5, how knowledgeable do you feel about the negative impacts of light pollution on human health?
- On a scale of 1 to 5, how important do you think it is to preserve dark skies for future generations?
- On a scale of 1 to 5, how likely are you to support policies and initiatives aimed at reducing light pollution?
- On a scale of 1 to 5, how much do you believe that reducing light pollution can enhance the visibility of celestial objects and improve astronomical research?

**Data Compilation:** The survey was distributed to a total of 150 individuals, primarily in high schools and a few colleges, as well as neighboring areas in the region. The distribution aimed to capture a diverse sample of participants across various age groups. A breakdown of participants included 99 individuals aged 15-19, 34 individuals aged 20-29, 11 individuals aged 30-49, and 6 individuals aged 50 or above.

The results of the survey were compiled and statistically analyzed. To identify relationships between variables, including correlations between survey responses, a Pearson product-moment correlation coefficient (Pearson's r) was utilized (Puth, Marie-Therese et al). The formula for Pearson's r is given by:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Figure 3: Pearson product-moment correlation coefficient Formula

This formula helped in quantifying the strength and direction of relationships between survey questions and other variables of interest. The analysis enabled a deeper understanding of how public perceptions and awareness of light pollution relate to factors such as age, education, and stargazing habits.

## Results

### Observational Data: Stargazing Conditions in Jammu

The observational phase of this study aimed to assess the quality of stargazing conditions in the regions of Jammu. A combination of SQM measurements, Lux levels, lunar phases, and NELM was analyzed to provide insights into the impact of light pollution and lunar phases on stargazing conditions.

**SQM Measurements and Stargazing Conditions** The SQM measurements, ranging from approximately 18.32 to 19.28 mag/arcsec<sup>2</sup> (Figure 4), reveal the state of light pollution in the selected regions. These measurements corroborate the pervasive issue of light pollution in the areas, impacting stargazing conditions. They provide quantitative data to support the qualitative observations of stargazers who have noticed a decline in the visibility of celestial objects in these regions .

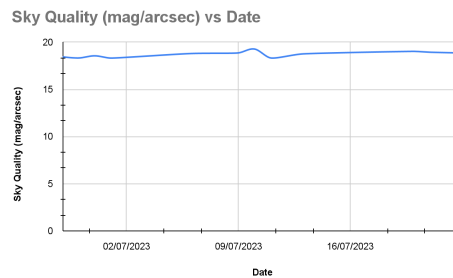


Figure 4: Graph of SQM vs Date

The strong negative correlation between SQM readings and Lux levels (lm/m<sup>2</sup>) (Figure 5) underscores the influence of artificial lighting on stargazing conditions. The more significant the light pollution, as indicated by higher Lux levels, the lower the SQM values. This correlation reaffirms findings from various studies that have consistently demonstrated how excessive artificial lighting adversely affects the visibility of celestial objects (Aubé, Martin et al).

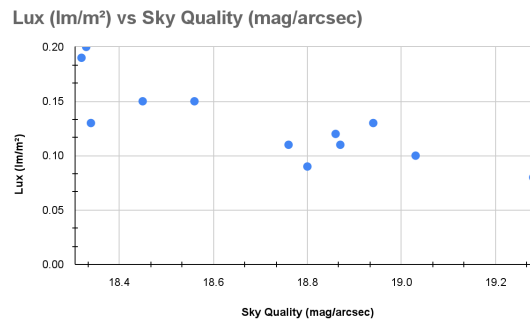


Figure 5: Graph of Lux vs SQM

**Moon Phase and SQM:** Moon phases significantly influence the SQM readings, illustrating

their impact on light pollution. The moon phase, expressed as a percentage of illumination (Figure 6), offers insight into how celestial visibility changes with lunar phases.

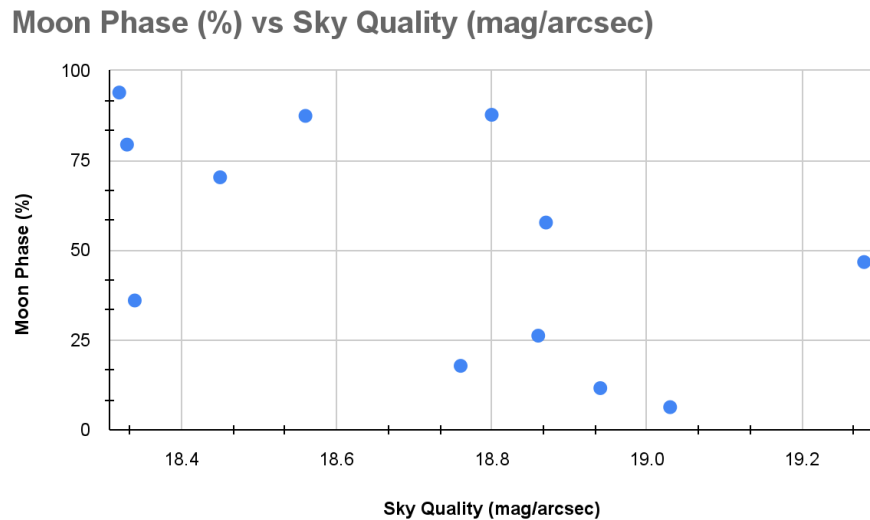


Figure 6: graph of Moon Phase vs SQM

As the moon's illumination decreases, SQM values tend to increase (Figure 6). This relationship signifies that during phases of lower lunar illumination, when the night sky is darker, light pollution diminishes, and stargazing conditions improve. Studies have consistently supported these findings, emphasizing the need to consider lunar phases when planning stargazing activities and assessing the impact of light pollution (Spitschan, Manuel, et al).

The influence of lunar phases on light pollution highlights the dynamic nature of stargazing conditions and the significance of understanding how this natural factor interplays with artificial lighting to affect celestial visibility. These findings emphasize the importance of considering both environmental and astronomical variables in assessing the quality of stargazing experiences in Jammu. In summary, the SQM measurements and their correlation with Lux levels and NELM affirm the detrimental impact of light pollution on stargazing conditions in the study regions. The link between lunar phases and SQM readings underscores the importance of considering celestial factors when addressing light pollution.

### Survey Results

The survey encompassed 150 respondents across different age groups, including 99 participants aged 15-19, 34 between 20-29 years, 11 respondents aged 30-49, and 6 individuals aged 50 or above. The survey primarily focused on assessing the public's perception and awareness of light pollution.

*Stargazing Frequency:* A major finding of the survey was the significant variation in stargazing frequency among different age groups. While the majority of respondents aged



15-19 (75%) reported stargazing occasionally, this percentage decreased to 41% among those aged 20-29, and further dropped to only 18% among individuals aged 30-49 and 50 or above. This disparity highlights the generational shift in stargazing habits.

*Familiarity With Light Pollution:* Surprisingly, the survey revealed that familiarity with the term "light pollution" didn't necessarily correlate with stargazing frequency. A substantial number of respondents (35%) in the 15-19 age group were moderately to extremely familiar with light pollution, while only 6% of the same group reported regular stargazing.

*Impact of Light Pollution:* As for the perceived impact of light pollution on visibility of stars and celestial objects, the majority of respondents (74%) believed that light pollution significantly hindered their ability to see stars, irrespective of their stargazing frequency. Interestingly, 84% of those aged 15-19 expressed this concern.

*Interest in Learning More About Light Pollution:* A noteworthy observation was the significant interest in learning more about the impacts of light pollution and ways to reduce it. Over 70% of respondents across all age groups indicated moderate to extreme interest in this area. This could signify an untapped enthusiasm for awareness and advocacy efforts. Next, let's delve into the results using the Pearson correlation coefficients from the correlation table to understand the relationships between different variables:

Age	1.00																		
Stargazing Frequency	-0.12	1.00																	
Familiarity With Light Pollution	0.11	0.30	1.00																
Impact On Visibility Of Stars	-0.05	0.26	0.40	1.00															
Concern About Light Pollution	0.14	0.13	0.28	0.20	1.00														
Impact On Quality Of Life	0.02	0.18	0.26	0.36	0.29	1.00													
Interest In Light Pollution Impacts	0.12	0.04	0.13	0.23	0.29	0.35	1.00												
Knowledge Of Light Pollution Health	0.00	0.32	0.25	0.09	0.25	0.11	0.14	1.00											
Importance Of Preserving Dark Skies	0.00	0.21	0.04	0.28	0.08	0.31	0.16	0.07	1.00										
Likelihood To Support Policies	-0.01	0.10	0.07	0.25	0.11	0.28	0.22	0.12	0.31	1.00									
Belief Light Pollution Hinder Visibility	-0.21	0.18	0.13	0.31	0.00	0.14	0.18	0.05	0.23	0.23	1.00								
	Age	Stargazing Frequency	Familiarity With Light Pollution	Impact On Visibility Of Stars	Concern About Light Pollution	Impact On Quality Of Life	Interest In Light Pollution Impacts	Knowledge Of Light Pollution Health	Importance Of Preserving Dark Skies	Likelihood To Support Policies	Belief Light Pollution Hinder Visibility								

Figure 7: Pearson product-moment correlation coefficient Table

## Correlations and Interpretations

The correlation table reveals moderate to good correlations between various survey questions:

*Age vs. Stargazing Frequency (-0.12):* The negative correlation of -0.12 between age and stargazing frequency indicates that as individuals grow older, they tend to stargaze less frequently. This suggests that there is an age-related pattern in stargazing behavior. Younger individuals are more likely to engage in stargazing activities, potentially due to greater interest, accessibility to stargazing opportunities, or educational exposure. As people age, other life priorities and responsibilities may reduce their stargazing frequency.

*Impact on Visibility of Stars vs. Belief Light Pollution Hinders Visibility (0.31)*: The positive correlation of 0.31 indicates a meaningful connection between an individual's perception of light pollution's impact on star visibility and their belief that light pollution hinders star visibility. Those who recognize light pollution's effect on star visibility are more likely to believe that it significantly hinders stargazing. This alignment between perception and belief underscores the importance of public awareness regarding the impact of light pollution on stargazing experiences.

*Familiarity with Light Pollution vs. Impact on Visibility of Stars (0.40)*: The strong positive correlation of 0.40 emphasizes the relationship between an individual's familiarity with the concept of light pollution and their belief in its impact on the visibility of stars. Those who are more familiar with the term "light pollution" are more likely to perceive it as a significant factor affecting star visibility. This highlights the role of education and awareness in shaping public perceptions of light pollution's consequences for stargazing.

*Impact on Quality of Life vs. Interest in Light Pollution Impact (0.35)*: The positive correlation of 0.35 suggests that individuals who consider light pollution as having a notable impact on their quality of life are more interested in exploring its broader effects. This alignment between perceived personal impact and curiosity about broader implications indicates that lived experiences are motivating individuals to learn more about light pollution and its multifaceted consequences.

*Importance of Preserving Dark Skies vs. Likelihood to Support Policies (0.31)*: The positive correlation of 0.31 reveals that those who place importance on preserving dark skies are more likely to support policies aimed at reducing light pollution. This relationship suggests that individuals who value the preservation of natural, unpolluted night skies are inclined to back regulatory measures that align with this goal. Such a correlation indicates public support for policy initiatives to mitigate light pollution.

The moderate to good correlations reveal significant associations between various survey variables, offering nuanced insights. Stargazing frequency is inversely related to age, indicating that younger individuals stargaze more frequently. Furthermore, those who recognize the impact of light pollution on star visibility are more likely to believe it hinders stargazing experiences. Familiarity with light pollution strongly links to perceiving its influence on star visibility, underscoring the role of education in shaping perceptions. Interest in light pollution's impact aligns with the perceived effect on the quality of life, highlighting the personal dimension of public interest in the subject. Moreover, the importance ascribed to preserving dark skies corresponds with the likelihood of supporting policies targeting light pollution reduction.

These findings are pivotal for designing targeted awareness campaigns, educational initiatives, and advocacy strategies. They can engage stargazers, enhance public awareness, and promote measures to address the implications of light pollution effectively.

## Discussion

The observational data collected in this study vividly illustrates the substantial challenge posed by light pollution to stargazing in the regions of Jammu. The observable trend, as indicated by the Sky Quality Meter (SQM), reveals relatively high light pollution levels. With an average SQM value of approximately 18.6 mag/arcsec<sup>2</sup>, these regions fall into the category of "Class 5" on the Bortle Scale, characterized by heavy light pollution (Bortle). This level of light pollution is detrimental to stargazing and reflects the increasing urbanization in the region, where artificial lighting increasingly encroaches upon the once-pristine night skies. Moreover, the Naked Eye Limiting Magnitude (NELM) values, determined through reputable sources such as 'Cleardarksky.com,' indicate that the faintest stars visible to the naked eye under these sky conditions generally ranged between 3.2 to 5.0. These values directly reflect the extent to which artificial lighting affects celestial object visibility. The observed NELM values are consistent with regions afflicted by Class 5 light pollution on the Bortle Scale, where faint stars are scarcely visible (Bortle).

Furthermore, the correlation analysis offers profound insights. It demonstrates that SQM has a strong negative correlation with the visibility of celestial objects. In essence, the more intense the artificial lighting, indicated by higher SQM values, the more it diminishes the visibility of stars and celestial objects. This finding aligns with prior research showcasing how excessive artificial lighting negatively affects stargazing conditions (Cinzano et al.). To address the issue of light pollution effectively, initiatives must focus on community involvement and policy advocacy. As artificial lighting increasingly encroaches upon the night skies, efforts should be concentrated on engaging local communities and government bodies in implementing policies and initiatives aimed at reducing light pollution. Public outreach, educational programs, and support for preserving dark skies are paramount. It is vital to collaborate with local communities and policymakers to curb light pollution effectively. The findings of this study underline the critical need for public awareness campaigns, community involvement, and policy advocacy to combat the issue of light pollution in the regions of Jammu and Kashmir. As artificial lighting continues to erode the night skies, the study underscores the pressing importance of public education, community initiatives, and support for dark sky policies in preserving the celestial wonders of this culturally significant territory.

The research, by elucidating the challenges posed by light pollution and exploring the intricate relationships between stargazing, public perceptions, and light pollution awareness, offers a foundation for future research and initiatives aimed at mitigating the adverse effects of artificial lighting on the night skies in Jammu and Kashmir.

## Limitations

While the present study provides valuable insights into the impact of light pollution on stargazing experiences in the regions of Jammu and Kashmir, several limitations should be acknowledged. *Sample Size and Demographics*: The survey sample predominantly consists of

individuals aged 15 to 29 years, primarily high school students. A more diverse age and occupational demographic would enhance the study's generalizability.

*Self-Reported Data:* The data collected through surveys is self-reported, which might introduce response bias. Future studies could employ more objective measurements.

*Regional Focus:* This research primarily concentrates on specific areas in Jammu. Expanding the study's geographical scope to include other regions would provide a more comprehensive understanding of light pollution's regional variation. *External Factors:* Factors such as light source types, building designs, or streetlight models weren't examined in depth. Future studies should delve into the impact of these specific factors on stargazing conditions .

### **Future Directions**

Despite the aforementioned limitations, this study offers a foundation for future research endeavors. Some potential areas for further investigation include :

*Extended Demographic Studies:* Expanding the survey to encompass a broader age range, diverse occupations, and different regions within Jammu and Kashmir and other regions can provide a more holistic perspective on the impact of light pollution.

*In-Depth Lighting Analysis:* A detailed analysis of the types and models of streetlights, household lighting, and their collective impact on sky brightness is essential to understanding the sources of light pollution in the region.

*Health and Ecological Impact Studies:* Investigating the potential health implications of light pollution on residents and its effects on the local ecology can contribute to a comprehensive understanding of the issue.

### **Conclusion**

In conclusion, this study provides a unique perspective on the changing stargazing conditions in the regions of Jammu, emphasizing the impact of urban development and artificial lighting. The observational data, along with the survey results, underscore the importance of understanding and mitigating light pollution for both recreational stargazers and future astronomical research.

While certain limitations exist, including sample size and regional focus, the moderate to good correlations found in the survey data offer valuable insights into the relationships between stargazing frequency, concern about light pollution, and interest in understanding its impacts. These findings can guide targeted awareness campaigns and advocacy efforts aimed at raising public consciousness regarding the consequences of light pollution.

### **Acknowledgements**

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### Works Cited

- “What Is Light Pollution?” International Dark-Sky Association. Accessed June 10, 2023.  
<https://darksky.org/resources/what-is-light-pollution/>.
- Chepesiuk, Ron. "Missing the dark: health effects of light pollution." (2009): A20-A27.
- Longcore, Travis, and Catherine Rich. "Ecological light pollution." *Frontiers in Ecology and the Environment* 2.4 (2004): 191-198.
- Ankita Sharma, Ankita, Parmil Kumar, and Bhagwati Sharma. "Jammu and Kashmir: A Paradise on Earth and the other side of the Story!" *International Journal of Research in Social Sciences*, vol. 6, no. 8, 2016, p. 33.
- "Govt sanctions 19,000 solar street lights for Jammu and Kashmir." *Economic Times*, 28 May 2021.  
<https://economictimes.indiatimes.com/industry/renewables/govt-sanctions-19000-solar-street-lights-for-jammu-and-kashmir/articleshow/83038252.cms?from=mdr>
- Mander, Susan, et al. "How to measure light pollution-a systematic review of methods and applications." *Sustainable Cities and Society* (2023): 104465
- Puth, Marie-Therese, Markus Neuhäuser, and Graeme D. Ruxton. "Effective use of Pearson's product–moment correlation coefficient." *Animal behaviour* 93 (2014): 183-189.
- Aubé, Martin, Johanne Roby, and Miroslav Kocifaj. "Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility." *PloS one* 8.7 (2013): e67798.
- Spitschan, Manuel, et al. "Variation of outdoor illumination as a function of solar elevation and light pollution." *Scientific reports* 6.1 (2016): 26756.
- Bortle, John E. "The Bortle Dark-Sky Scale." *Sky and Telescope* (2001)
- Cinzano, Pierantonio, Fabio Falchi, and Christopher D. Elvidge. "The first world atlas of the artificial night sky brightness." *Monthly Notices of the Royal Astronomical Society* 328.3 (2001): 689-707.

## **The Relationship Between Student Demographics, School Resources, and School Performance in OCPS HS By Cristina Socas**

### **Abstract**

In the United States, school quality varies significantly, leading to differences in long-run outcomes such as educational attainment and job opportunities both across and within different demographic groups. I am particularly interested in studying variation in school quality within the Orange County Public High School system in Orlando, Florida, as I live within the Orange County Public Schools (OCPS) boundaries and have heard of disparities between high schools within the district. Orange County Public Schools are assessed via a grading system in the County. Through analysis of published data, I sought to examine the effects of school funding, student-to-teacher ratios, racial distributions, and family economic distribution as potential contributors to a school's overall grade. The analyses showed that zoning boundaries separating students from varying socioeconomic standards have greatly affected the performance of different OCPS schools due to the socioeconomic rules used for the drawing of these boundaries. These boundary lines have negative effects on not only low-income students' facilities and experiences during their elementary to high school academic careers, but on their futures as a whole due to the disadvantages that an unequal education harbors. The results offer insight into the disparities seen in the school rating performances of Orange County's High Schools and may contribute to future policies regarding the drawing of school boundary lines.

### **Introduction**

Throughout the United States, there are approximately 98,000 public schools. These schools help to educate the next generation, and they build the future of the country. According to EdBuild, predominantly non-white school districts receive \$23 billion less in funding compared to that of majority white school districts. Although these disparities in funding and education sometimes are rooted in the classroom, there are also an abundance of them outside of the classroom, and in the school board conference room when district zones are being drawn. Existing research concludes that the drawing of school zones prevents certain children from getting the same caliber of education, even when funding is equalized across schools. When talking about the stress this puts on lower income families in a report, The United States Congress Joint Economic Committee states, "A nationally representative survey of homebuyers found half of households with children consider school district quality when selecting a neighborhood during home buying" and a recent study found low-income families with Section 8 housing vouchers cited "better schools" as their primary motive for moving neighborhoods. However, many Americans say they are prevented from moving to a better neighborhood due to high housing costs."

According to a 2012 Brookings report, "Low-income students who attend top schools score two percent higher than state averages. Low-income students attending low-performing schools score 18.5 percent below average." Brookings talks about the root of this, and the toll



that can take, saying, “Restrictive zoning laws are widespread. Brookings reports that 84 percent of municipalities impose some minimum lot size, the average being 0.4 acres.” The authors note that this is larger than the average lot size of a single-family home in America — 0.26 acres. In other words, in most places it’s illegal to build a home of typical size. The authors report that these laws “effectively block low-income students and their families from living near or attending” public schools where students perform well on state exams. In areas with large lot laws, it is significantly more expensive to live near good public schools than it is in areas without restrictive zoning, according to the study.

There is much evidence that connects a sharp difference in school quality with the areas these schools are built in, and the demographics they are made for. According to the UNCF, students of color are often concentrated in schools with fewer resources. Schools with 90 percent or more students of color spend \$733 less per student per year than schools with 90 percent or more white students. Additionally, African American students are often located in schools with less qualified teachers, teachers with lower salaries, and novice teachers. These disparities in access to education by demographics date back to the 1920s, with American cities being drawn with redlining, excluding and secluding certain races into consolidated areas, and withholding their mortgages, loans, and insurance, hurting these areas and leaving them with little money. Throughout time, these redlined areas have grown and become more blended, but the effects of the 1920s practice are still prevalent and affect the areas today.

According to the Orlando Weekly, “Orlando has shown considerable progress since the Fair Housing Act of 1968, but racially divided residential patterns remain deeply embedded and are plainly obvious when you look at the map and notice how I-4 cuts through Orlando like a picket line. Many of Orlando's segregation issues stem from what's referred to as "redlining," which was a discriminatory practice widely used in the 1920s and 30s to selectively control where people of color could buy property, and we're still dealing with its effects. This is one of the reasons why Winter Park and College Park are still whiter than ever.” The schools in OCPS, while not far apart, have educational standards that are miles apart. The answer to disparities between schools may be in Florida’s history. In a 2017 study done by the LeRoy Collins Institute, the findings indicate that, “More than one-third of Hispanic students and one-third of black students attend an intensely segregated K-12 school in Florida, and Black and Hispanic students are more likely to attend school with students living in poverty than white and Asian students.” The institute concluded that Florida’s schools are becoming resegregated, with Hispanic enrollment increasing and more and more schools becoming dominated by certain demographics, rather than the real blend of cultures and people that Florida really is, as Florida is 27% Hispanic, 15.9% African American, and around 52% white, but the schools do not reflect this.

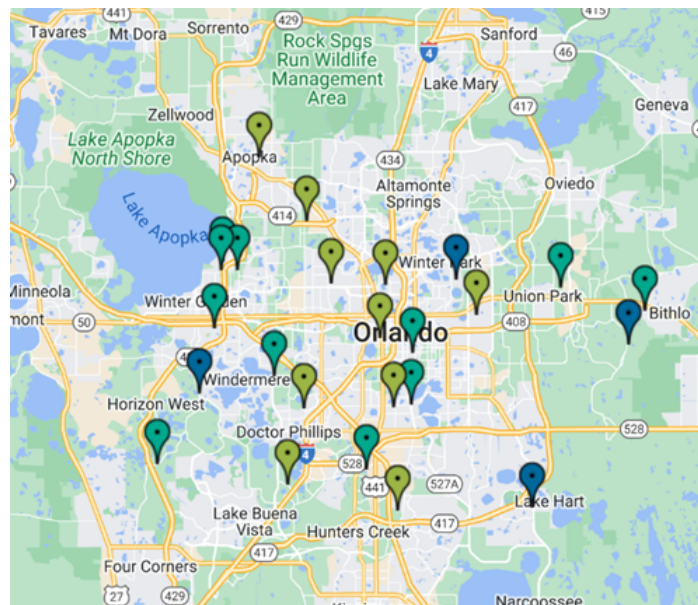
Throughout Florida, the Florida Department of Education (FDOE) provides a grading system to rate schools’ performance. According to the FDOE website, “School grades provide an easily understandable way to measure the performance of a school. Parents and the general

public can use the school grade and its components to understand how well each school is serving its students. Schools are graded A, B, C, D, or F.”

This research article focuses on various factors from school to school in order to evaluate which factors may contribute to the differences in school grades in Orange County High Schools. Specifically, funding, student-to-teacher ratios, demographics, and economic distributions will be assessed, as the data for these factors can be found in the school and state published data and information.

## Methods

To look at differences across high schools in OCPS, I utilized the Florida Department of Education’s published Report Cards data for all 25 high schools in the district in the school year 2021-2022. As can be seen in the map below, four of the high schools have an A score, 11 have a B score, and 10 have a C score. The lowest possible score is an F - while none of the high schools received an F score, three of the elementary schools in the district did. Notice that there is variation in school report card schools within geographic areas, all 4 schools rated A are spread out throughout the county.



**Figure 1.** Distribution of grades for High Schools in the Orange County Public School System.

Legend:

Dark blue - Rated an A on the Florida school report card

Green - Rated a B on the school report card

Lime Green - Rated a C on the school report card

After downloading this report card data, I visualized it using tables and graphs to determine whether certain measures were related to a school’s report card score along the various test points that I was assessing.

### Question 1: The Impact of Funding

In order to assess the funding that schools in the OCPS system receive, data and information regarding funding sources were collected from the official adopted and approved budget distributed online by the Office of Management and Budget for the Orange County Public Schools.

In addition to examining income to the schools, any thorough analysis must also look at the cost per student, to see if there is a discrepancy in the resources and expenses a high school must utilize in working with its student population. The Florida Department of Education publishes data regarding per-student expenditures for each high school on its website. Data was gathered from the published results.

High school funding and distribution were assessed. The cost per student in expenses was gathered in a table, averaged for the school report card grades, and then plotted, along with their standard deviation, in relation to school grades to ascertain if there was any pattern in the cost-per-student expenses.

### Question 2: What is the Demographic Distribution?

Assessment of the demographics for the various high schools was obtained via each school's published "report card" data. Every Orange County Public School (with the exception of charter schools) publishes data regarding its school's demographics, regarding student race and ethnicity, along a 5 category system. The categories are: white, Hispanic, black, Asian, or multiple. Additionally, information is provided in the demographic system showing ELL (English language learner students for whom English is not the primary language) and ESE (students with documented disabilities) categories.

For the charter schools, demographic data was gathered from the current Florida Department of Education website. These schools were: Cornerstone Charter High School, Innovation Montessori, Legacy High School. Additionally, Lake Buena Vista High School and Horizon High School did not have their school report cards on the OCPS website and therefore their data was taken from the Florida Department of Education current data.

Demographic data was gathered for the various schools and graphed against the school report card grades. The mean and standard deviation were calculated and placed on the graph.

### Question 3: Is there a difference in the Student per teacher ratio?

The Florida Department of Education website provides the number of students and the number of teachers per school. This data was tabulated and a Student per Teacher Ratio was calculated.

### Question 4: Does the Economic Distribution of students play a role?

The Florida Department of Education website provides data regarding the percentage of economically disadvantaged students per school. Data was collected and placed into tabular form. The percentages were then averaged per school report card grade in order to show the percentage of economically disadvantaged students.

## Results–Funding

After analyzing the published budget documents, I learned that schools in Orange County Public Schools, or OCPS, which spans for the majority of central Florida, are funded relatively equally. For context, OCPS has 127 elementary schools, 38 middle, 9 K-8, 20 high schools, and 8 exceptional/alternative schools. Analysis of the OCPS funding documents for the 2021 fiscal year shows that all property taxes in the county come together and each school gets the same amount of money per student, with more funding actually being given to schools in disadvantaged neighborhoods, in order to attempt to level the playing field.

In the adopted budget summary of the OCPS 2022-2023 fiscal year, the budget is split into 5 different sections (the operating budget, the capital budget, debt service, special revenue funds and internal service funds), and then gets appropriated accordingly. The same amount of money is given to the schools, at around \$13,000 per student according to the 2020-2021 expenditures per full time equivalent student report. Thus, overpopulated schools receive more total funding to help regulate overpopulation, as they have more students.

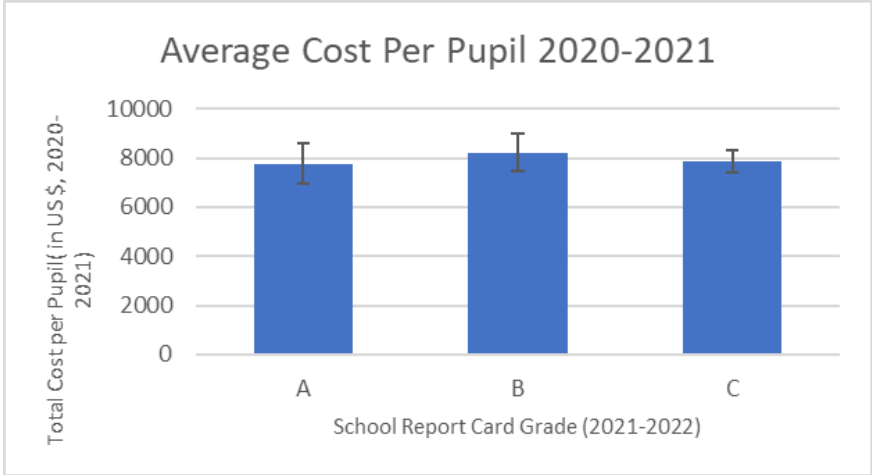
However, in practice, although the district budgets the same amount of money per student, schools have varying per-student expenditures. Looking at the 25 high schools in the district, cost per student in the academic year 2020-2021 varied from \$7,015 - \$9,966 (with two schools not reporting cost per student).

School Name	2021-2022 School Grade	2020-2021 Cost per Pupil
Apopka HS	C	\$7,015
Colonial HS	C	\$7,751
Cornerstone Charter HS	B	\$7,936
Cypress Creek HS	C	\$7,841
Dr Phillips HS	C	\$7,642
East River HS	B	\$8,595
Edgewater HS	C	\$8,252
Freedom HS	B	\$7,742
Horizon HS	B	not reported
Innovation Montessori HS	B	\$8,560
Jones HS	C	\$8,696
Lake Buena Vista HS	C	not reported
Lake Nona HS	A	\$7,122
Legacy HS Charter	B	\$9,966
Maynard Evans HS	C	\$7,641
Oak Ridge HS	C	\$7,963
Ocoee HS	B	\$7,342
Olympia HS	B	\$7,478

Timber Creek HS	A	\$7,834
University HS	B	\$8,070
Wekiva HS	C	\$7,798
West Orange HS	B	\$8,582
William R Boone HS	B	\$8,018
Windermere HS	A	\$7,068
Winter Park HS	A	\$8,192

**Table 1.** Data showing cost per pupil reported for 2020-2021 per school, alongside each school’s reported school grade for 2021-2022

First, I plot the average total cost per pupil in 2020-2021 by school report card score in Figure 2. As can be seen below, when the total costs per pupil are averaged across schools by school report card grade, there is no noticeable difference between the schools with high grades and ones with lower grades. A schools have an average cost per pupil of \$7,554, while B schools have an average of \$8,229, and C schools have an average cost per pupil of \$7,844.



**Figure 2.** Average Total Cost per Pupil in School Year 2020-2021 grouped by 2021-2022 School Report Card Grade

**Demographics**

Data regarding school demographics were tabulated showing the percentages of white, hispanic, and black students at the various high schools.

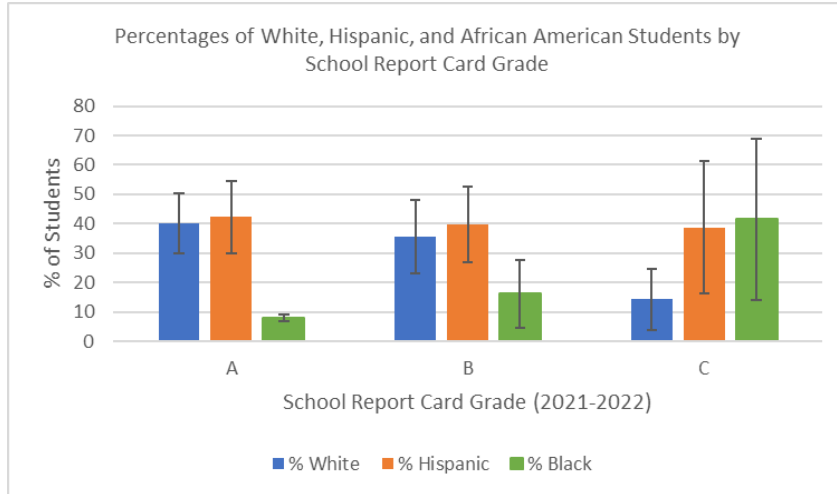
School Name	2021-2022 School Grade	% White	% Hispanic	% Black
Apopka HS	C	30.7	32.8	31.9
Colonial HS	C	10.7	74.4	11
Cornerstone Charter HS	B	39.3	42.8	9.1

Cypress Creek HS	C	10.2	67	13.4
Dr Phillips HS	C	22.8	39.3	29.2
East River HS	B	38.3	42.3	12.2
Edgewater HS	C	26.7	18	48.6
Freedom HS	B	17.4	64.5	9.8
Horizon HS	B	39.2	45.8	8.2
Innovation Montessori HS	B	46.4	36.3	8.9
Jones HS	C	1.5	11	87
Lake Buena Vista HS	C	19	57.6	13.4
Lake Nona HS	A	26	59.6	7
Legacy HS Charter	B	53.8	21.6	18.1
Maynard Evans HS	C	1.5	10.7	84.1
Oak Ridge HS	C	4.3	44.6	47.9
Ocoee HS	B	18.4	27.2	46.6
Olympia HS	B	30.1	32.2	26.6
Timber Creek HS	A	39.8	40.3	9.5
University HS	B	18.9	56.7	11.6
Wekiva HS	C	15.2	31	48.5
West Orange HS	B	44.3	28.3	17.3
William R Boone HS	B	45.1	40.1	9.4
Windermere HS	A	45.1	38.4	7.3
Winter Park HS	A	49.3	30.9	8.4

**Table 2.** Data showing racial demographics reported for 2021-2022 per school, alongside each school's reported school grade for 2021-2022

When looking at demographics of students such as race, the proportion of Hispanic students enrolled in OCPS high schools does not differ much by school ratings, as seen in Figure 3. However, schools with lower school report card ratings have significantly larger percentages of students that are African-American than those with higher grades. On average, about 8% of students are African-American at A rated schools, compared to 16% in B schools and 42% in C schools. Comparatively, 43% of students at A schools are Hispanic, compared to 41% at B rated schools, and 39% at C rated schools. It is not very surprising that the population of Hispanic students is very large in all schools, as Orange County, Florida has a large Hispanic population. The number of white students decreases from 40% average at A rated schools, down to 14% at C rated schools.

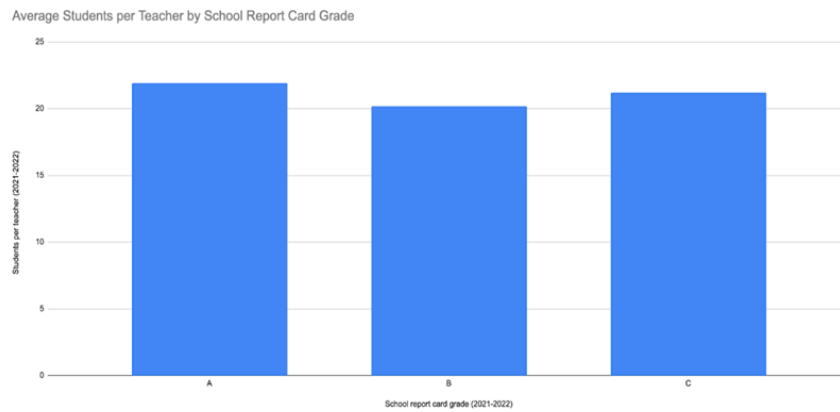
The decrease in white students from A to C schools is a statistically significant difference. Additionally, the increase in the number of black students from A schools to C schools is also a statistically significant difference.



**Figure 3.** Graph showing average percentages of Hispanic and Black students reported for 2021-2022 grouped by School Report Card Grade

**Student-to-Teacher Ratio**

One factor that has been shown to vary across high and low performing schools has been the number of students per teacher. Taking the average students per teacher at OCPS high schools by report card score, I see little variation in the number of students per teacher in A, B, and C-scored schools, as shown in Figure 4. A schools have an average student to teacher ratio of 22, similar to that of B schools, which have an average of 20, and C schools which have an average of 21. As such, the student to teacher ratio, as proven by Figure 3, does not seem to be causing differences in educational performance across OCPS high schools.



**Figure 4.** Average students per teacher reported for 2021-2022, grouped by 2021-2022 school report card grade

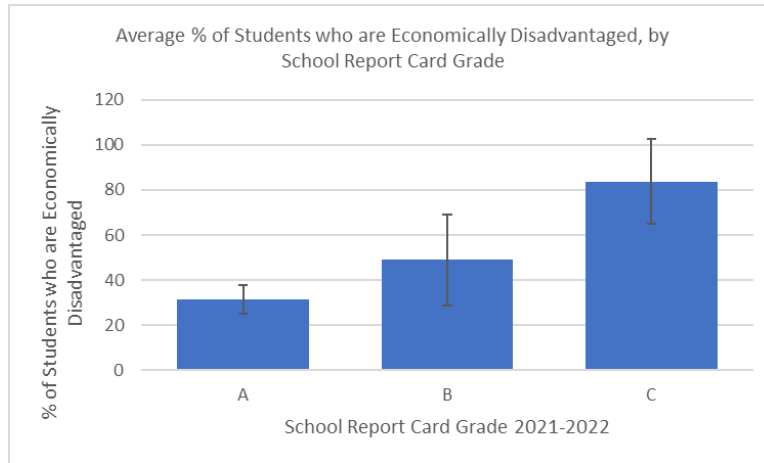
**Economic Distribution**

Finally, I looked at the percentage of economically disadvantaged students across schools with differing report card grades.



School Name	2021-2022 School Grade	% Economically Disadvantaged
Lake Nona HS	A	33.7
Timber Creek HS	A	32.7
Windermere HS	A	22.2
Winter Park HS	A	36.6
Cornerstone Charter HS	B	33.4
East River HS	B	72.5
Freedom HS	B	53.3
Horizon HS	B	22
Innovation Montessori HS	B	31
Legacy HS Charter	B	
Ocoee HS	B	80.4
Olympia HS	B	47.1
University HS	B	71.5
West Orange HS	B	34.1
William R Boone HS	B	44.4
Apopka HS	C	67.6
Colonial HS	C	99.1
Cypress Creek HS	C	69
Dr Phillips HS	C	69.8
Edgewater HS	C	83.8
Jones HS	C	100
Lake Buena Vista HS	C	48.7
Maynard Evans HS	C	100
Oak Ridge HS	C	100
Wekiva HS	C	99

**Table 3.** Data showing percentage of economically disadvantaged students per school, along with their respective school grade.



**Figure 5.** Average percentage of economically disadvantaged students grouped by 2021-2022 school report card grade.

Figure 5 (above) shows that as schools' ratings get lower, the average proportion of students who are economically disadvantaged within these schools increases. At A schools, about 25% of students are economically disadvantaged, compared to 44% at B schools, and 81% at C schools. There is a statistically significant difference in the number of economically disadvantaged students at C schools compared to A schools.

This could be due to the history of redlining in Florida, specifically Orange County as mentioned earlier. Although redlining occurred almost 100 years ago, the effects remain strong even today in public high schools.

## Discussion

Analysis of school funding showed that schools are apportioned funds equitably, with schools receiving approximately \$13,000 per student. Analysis of the OCPS funding documents for the 2021 fiscal year shows that all property taxes in the county come together and each school gets the same amount of money per student, with more funding actually being given to schools in disadvantaged neighborhoods, in order to attempt to level the playing field. Additionally, overcrowded schools receive more funds, as they have more students.

Understanding that the funding received by each school is approximately equal, I then assessed if students cost more at different schools. Did lower scoring schools expend disproportionately more money per student? The analysis did not bear this out when looking at the 2020-2021 data. In fact, the cost per student was relatively equal between schools that scored an A, B, or C.

Subsequent to investigating funding or expenditure differences, I looked at the racial demographics of the various schools and found that there was a staggering difference in the percentage of black students between the differently rated schools. Schools scoring an A rating had an average of 8% African American students, those scoring a B had an average of 16%, and schools scoring a C had 42% African American students. In fact, looking at the raw data, you can

see that two of the C schools (Jones and Maynard Evans) had a disproportionately high number of African American students, with both schools reporting rates greater than 80%. Hispanic students were relatively equal throughout the different schools, and made up a large portion of all of the schools, consistent with the large Hispanic population in Central Florida. White students made up a large portion of the A-rated schools (40%), whereas they represent an average of only 14% of the student body in the C-rated schools.

Analysis of the number of students and the number of teachers per school indicated that there was no significant difference between the student-to-teacher ratio of A, B, or C-rated schools. However, it is important to note that this ratio does not address whether the lower-performing schools have less qualified teachers, teachers with lower salaries, and novice teachers. Therefore, while the teacher ratios remain the same, there may be a difference in teacher quality not exposed by this data.

Economic distribution data showed striking differences between the school ratings. At A schools, about 25% of students are economically disadvantaged, compared to 44% at B schools, and 81% at C schools. It is interesting to note that 3 of the C-rated schools reported as having a population that was 100% economically disadvantaged (Jones, Maynard Evans, and Oak Ridge). When there is a school with 100% economically disadvantaged students, it cannot help but raise the question as to how boundary lines are drawn that encompass only the “poor” areas so completely. As mentioned earlier, this may have to do with the way the school boundaries are drawn.

In an attempt to see if this bears out in practice, I took a preliminary look at the school boundary lines published on the OCPS website. Winter Park High School is an A-rated school. Interestingly, the boundary lines are not drawn in an equal radius from the school. Rather, they encompass very well the higher income (green) area of an income map of the area

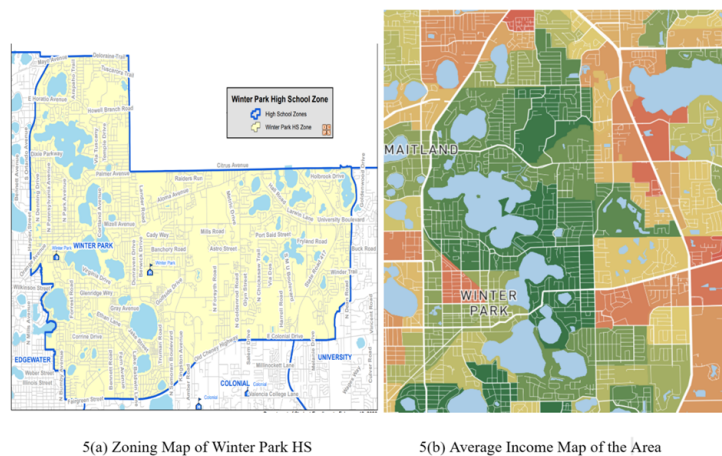
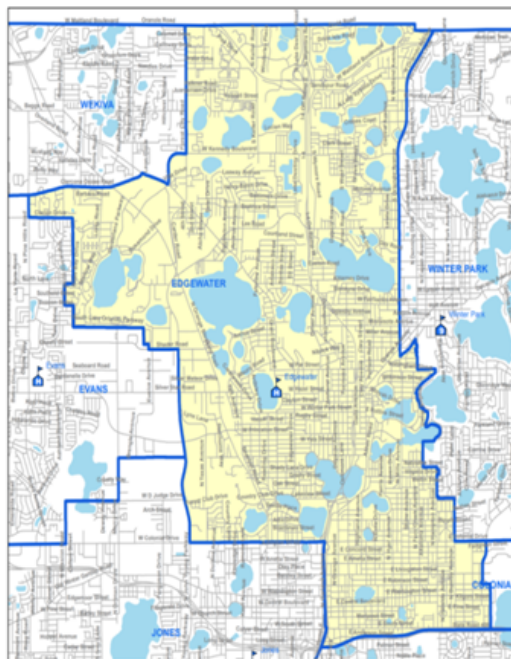
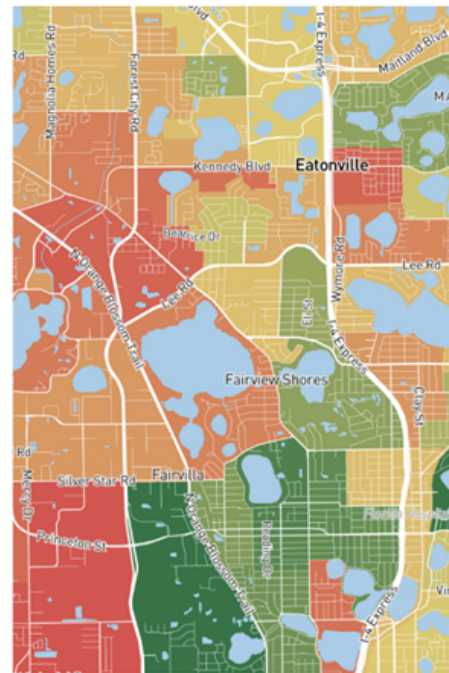


Figure 6. Panel showing the zoning map of Winter Park High School next to the Area Average Income

Immediately adjacent to Winter Park High School, to the West, is a C-rated school (Edgewater). The boundary lines are drawn to encompass many more low-income areas (yellow, orange, red) while seemingly skirting around some of the high-income green areas.



6(a) Zoning Map of Edgewater High School



6(b) Income Map for the same area

Figure 7. Panel showing the zoning map of Edgewater High School next to the Area Average Income

Examination of the drawing of the school boundary lines would be a good subject for continued and further research on this subject, and one that I may undertake in the future as a subsequent study to examine whether the boundaries could be redrawn to provide a more equal distribution of socioeconomic status throughout the schools.

These statistics, combined with existing evidence, help to highlight that the disparities between schools are not necessarily a result of differences in funding or student-to-teacher ratios, but are more associated with differences in race and socioeconomic status. These disparities can cause children in areas with more poorly performing schools to have a harder time getting further education, limiting their future opportunities and hurting the individuals and communities that live in those areas. This hurts the nation on a small and large scale, as individual people and the communities they live in can get stuck in a cycle of poverty and disadvantage, which will affect the country as a whole as unemployment, homelessness, and poverty rates continue to increase.

Schools, as an escape from one's home life and a provider of knowledge, can help break this cycle by encouraging and stimulating growth not only academically, but also emotionally and socially. As it stands, OCPS schools are not achieving what they could be, but perhaps they could reach their full potential by adding outreach and helpful programs. Some of these programs could include increased funding for after-school activities, public speaking, and

self-confidence programs, and the encouragement of school participation, which can help build disadvantaged communities up, rather than continue to allow them to break down. Helping English Language Learners (ELL) can also greatly benefit the community, as it will help to integrate and further educate students that may have a harder time learning due to a language barrier. Overall, helping these communities and schools will not only help those specific areas, but the effects can help on such a large scale, that the nation's economy can grow and improve.

## **Conclusion**

The analysis of the various factors in the Orange County High School system shows that there are statistically significant differences in the racial and socioeconomic distribution of students at A-rated schools vs C-rated schools. Returning again to the 2012 Brookings report, "Low-income students who attend top schools score two percent higher than state averages. Low-income students attending low-performing schools score 18.5 percent below average." Therefore, it is not the ability of the low-income students to learn, but rather the system that they are in that affects their educational outcomes.

Moving forward, efforts should be made to provide a higher caliber of education for all students and level the playing field. In an attempt to do so, I believe that zoning maps could be redrawn to provide a more equal distribution of socioeconomic status. For several schools, this could be accomplished without resorting to measures that extend far past the current school areas since the schools have zoning maps drawn that are not in an even radius around the school property. However, we know from The United States Congress Joint Economic Committee having stated, "A nationally representative survey of homebuyers found half of households with children consider school district quality when selecting a neighborhood during home buying"; that many families choose neighborhoods based on the public schools. Rezoning of schools would likely cause an outcry from homeowners or who purchased due to a particular school zone.

Another alternative could be the implementation of "school choice." Under this system, the students would be able to select their schools and the funding money would follow them to the school of their choice. This seems like a wonderful option; however, it is unknown what would happen to the most economically disadvantaged students--those students who do not have the resources to drive to a higher-rated school that is located miles from their homes. Additionally, when we consider family influences and generational poverty, it is unknown whether the parents of the students in the most economically disadvantaged areas have the resources or ability to enroll in the school choice paperwork.

While searching for the best solution, after-school programs and early learning opportunities that could help students from poorly performing areas to see education and learning in a positive light and provide access to resources that would help with school choice paperwork, if that becomes a reality, would be very helpful. Additionally, providing literature and language resources to those for whom early reading is not encouraged enough can

significantly improve not only literacy rates, but future education levels.

### **Limitations**

There are a few limitations within the study that I could not control for, but should mention here. As mentioned previously, the student-to-teacher ratio provides only a number while it may not reflect the quality of teachers or their experience. Another very important variable that I wish could have been qualified, because I feel that it must have a significant impact, is the parent involvement and familial attitude toward school success and learning. It is often the belief system that we grow up in that shapes our outlook and therefore the home life of students will certainly affect their school performance and that cannot be measured here.

One type of school that does reflect a family's emphasis on education is private schooling. Parents paying for their students' education is indicative of its importance in the home and also indicates a more economically advantaged situation. However, the data from private schools could not be included here because they are not graded by the Florida grading system and therefore the data is not available or comparable.

### **Acknowledgments**

I would like to thank my mentor for her guidance and assistance with this project.

## Works Cited

- Committee, United States Joint Economic. “Zoned out: How School and Residential Zoning Limit Educational Opportunity.” *Zoned Out: How School and Residential Zoning Limit Educational Opportunity*, United States Joint Economic Committee, USA Today, 12 Nov. 2019,  
<https://www.jec.senate.gov/public/index.cfm/republicans/2019/11/zoned-out-how-school-and-residential-zoning-limit-educational-opportunity>.
- Florida School Mapping Tool*, Florida Department of Education,  
<https://edudata.fldoe.org/ReportCards/Mapping.html>.
- “K-12 Disparity Facts and Statistics.” *UNCF*, UNCF, 20 Mar. 2020,  
<https://uncf.org/pages/k-12-disparity-facts-and-stats>.
- Orfield, Gary, and Jongyeon Ee. LeRoy Collins Institute, 2017, *Patterns of Resegregation in Florida's Schools*,  
[https://www.civilrightsproject.ucla.edu/research/k-12-education/integration-and-diversity/patterns-of-resegregation-in-floridas-schools/LCI-Tough-Choices-Patterns-of-Resegregation\\_FINAL.pdf](https://www.civilrightsproject.ucla.edu/research/k-12-education/integration-and-diversity/patterns-of-resegregation-in-floridas-schools/LCI-Tough-Choices-Patterns-of-Resegregation_FINAL.pdf). Accessed 2022.
- Roswell, Jonathan. *Housing Costs, Zoning, and Access to High-Scoring Schools*, Brookings, Apr. 2012,  
[https://www.brookings.edu/wp-content/uploads/2016/06/0419\\_school\\_inequality\\_rothwell.pdf](https://www.brookings.edu/wp-content/uploads/2016/06/0419_school_inequality_rothwell.pdf).
- “Tentative Budget Summary.” *FY23 OCPS Adopted Budget Summary*, 2022,  
[https://cdn5-ss15.sharpschool.com/UserFiles/Servers/Server\\_54619/File/Departments/Budget/FY23%20Budget%20Documents/FY23%20OCPS%20Proposed%20Tentative%20Budget%20Summary.pdf](https://cdn5-ss15.sharpschool.com/UserFiles/Servers/Server_54619/File/Departments/Budget/FY23%20Budget%20Documents/FY23%20OCPS%20Proposed%20Tentative%20Budget%20Summary.pdf).
- Wolf, Colin. “New Map Reminds Us That Orlando Remains Incredibly Segregated.” *Orlando Weekly*, Orlando Weekly, 14 Jan. 2023,  
<https://www.orlandoweekly.com/news/new-map-reminds-us-that-orlando-remains-incredibly-segregated-13828729>.



# Automated Quantification of Breast Cancer Marker Evolution from Serial Immunofluorescence Assays By Rikhil Rao

## Abstract

Despite advances in breast cancer diagnoses and treatment, it continues to be the second leading cause of cancer death in women. Recent interest in managing and prognosticating breast cancer has been centered around examining single-cell and spatial expression patterns on molecular imaging, such as immunofluorescence and immunohistochemistry <sup>1</sup>. However, current techniques for this single-cell quantification are disjointed and steps are not formatted to be compatible.

The purpose of this project is to develop a simple, easy to use, end-to-end pipeline to quantify how much a patient's cancer changes at different timepoints in their treatment. To accomplish this, serial cyclic immunofluorescence images acquired over the course of a patient's breast cancer treatment were gathered from the Human Tumor Atlas Network (HTAN). Two images of different samples were chosen from time point 0 and one image from time point 1 was chosen. Each image consisted of 25 unique channels, including DAPI, HER2, and ER. These images were used to train a patient-specific Variational Auto-Encoder (VAE), which was then used to quantify how much the cancer changed. In order to train the model, individual cells were segmented using an open-source tool called MCMICRO, resulting in around 14,000 cells in each image.

Automated single-cell quantification of marker expression in breast cancer can be important to track tumor evolution over time, which can be quantified, visualized, and predicted using a VAE.

## Introduction

Cancer has become one of the main threats to human health and life. Among all types of cancer, breast cancer is very common among women and diverse in character. About 70 percent of all breast cancers in women have overexpression of receptors (proteins) that attach to estrogen or progesterone <sup>2</sup>. Breast cancers without ER (Estrogen Receptor) and PR (Progesterone Receptor) are known as HR (Hormone Receptor)-negative. Estrogen receptor and progesterone receptor tests are used to help guide breast cancer treatment with hormonal chemotherapies such as tamoxifen <sup>3</sup>. However, patients with identical hormone receptor phenotypes can have variable responses to therapy <sup>4</sup>. Recent research shows that cancer cells and cells within the tumor microenvironment can have variable phenotypes across parts of the tumor, and more specific analysis of these distribution patterns can help determine disease progression and response to treatment <sup>5</sup>.

Immunofluorescence is a powerful approach for getting more information about cellular structures and biomarker expressions. Augment simple immunofluorescence, cyclic immunofluorescence (CyCIF) is a novel technique to study expressions and locations of a multitude of specific biomarkers in the same sample <sup>6</sup>. Since the extent of cellular heterogeneity



in breast cancer has been hypothesized to impact diagnosis, response to therapy, and long-term outcome, CyCIF of breast cancer biopsies has potential to guide breast cancer management in the future.

CyCIF generates gigabytes of image data that scientists and technicians do not have the bandwidth to process or ability to identify specific patterns. In contrast, artificial Intelligence based computational pathology has shown increased diagnostic accuracy and reduced turnaround times <sup>7</sup>. Computer aided image analysis of CyCIF data has the potential to make this complex information more accessible in the diagnostic workflow of breast cancer <sup>8</sup>. In this study, we show the feasibility of a fully automated deep learning-based pipeline for analysis and tracking of biomarker expression patterns in serial breast cancer biopsies.

## Results

The result is a pipeline that takes in a set of molecular imaging files (often 10-100 GB in size) and outputs the single cell quantification for each channel of the imaging.

### VAE Training

In the training dataset, the pipeline took an input of 30 channels (DAPI, HER, ER, PCNA, Ki67, etc.) and accurately segmented ~16,000 cells from which cell-specific marker expression quantifications were obtained. Execution of the pipeline on the testing datasets at the same and later time points resulted in ~21,000 and ~4000 identified and quantified cells, respectively. Figure 1 shows an exam cropped section of one of the biopsies run through the MCMICRO UNMICST cell segmentation algorithm.

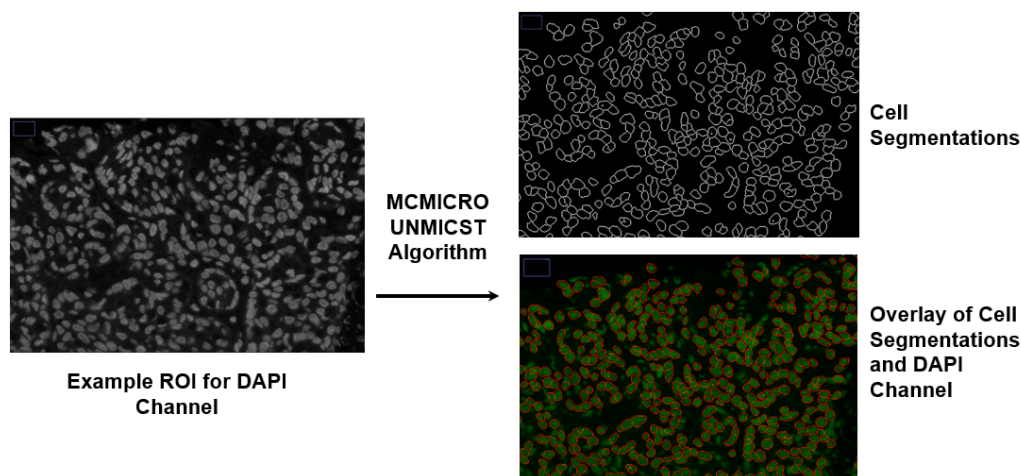


Figure 1: Example segmentation for one region of interest (ROI) from biopsy. Passing the image on the left through the MCMICRO pipeline generates the images on the right. The images on the right are the masks of the cells that were in the ROI.

### Marker Quantification Results

Looking at the quantification of the markers at different timepoints allows us to make claims about the cancer progression. For example, the increase in the expression of Ki67

indicates to us that cancer is proliferating at a much higher rate.

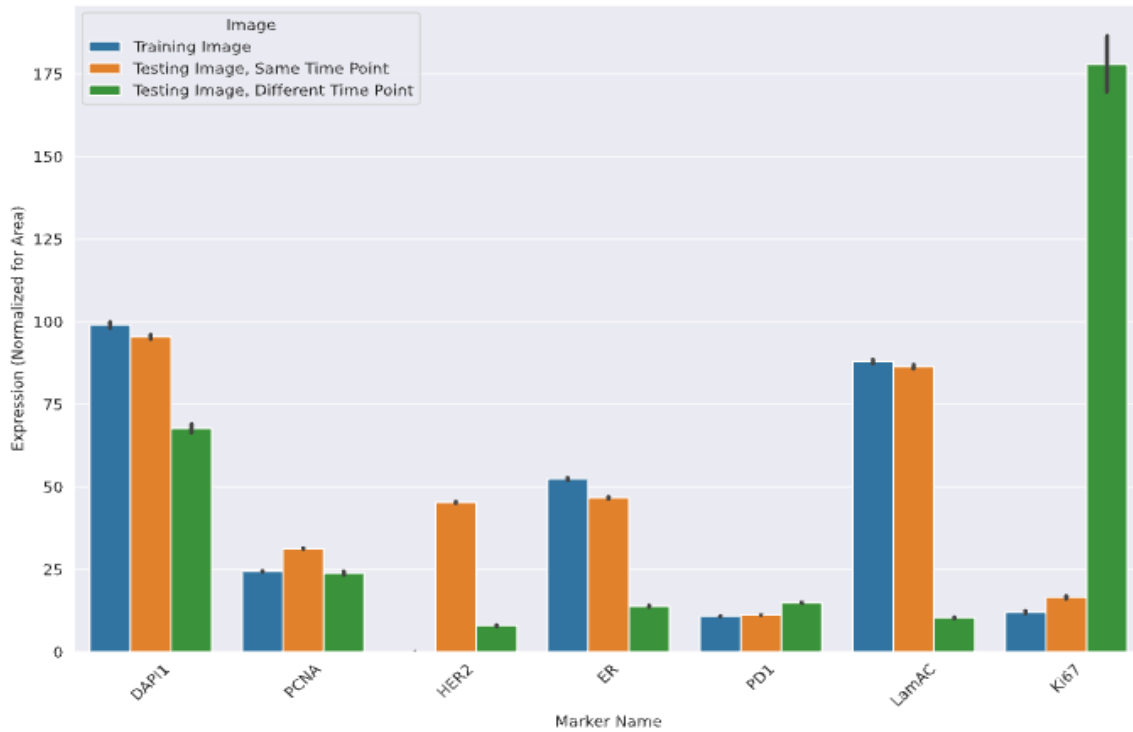


Figure 2: The concentration of several markers in various images at different timepoints

### VAE Training and Analysis

The VAE model was trained for 200 epochs and reached a test loss of 0.1159 and a validation loss of 0.1164. The training and testing loss is reflected in the quality of the image generated as seen in Figure 4. Figure 4 shows an image fed into the VAE and the rebuilt version of that image from the VAE. The drop in quality is because of the lack of latent vectors used to represent the 24x24 images but is necessary to interpreting the data in a friendly way. Figure 5 provides a visual representation of the latent vector at different timepoints and shows the difference between the timepoints. From the graphs a clear distinction between each timepoint can be compared using the KL Divergence Statistic to quantify the difference in between two timepoints.

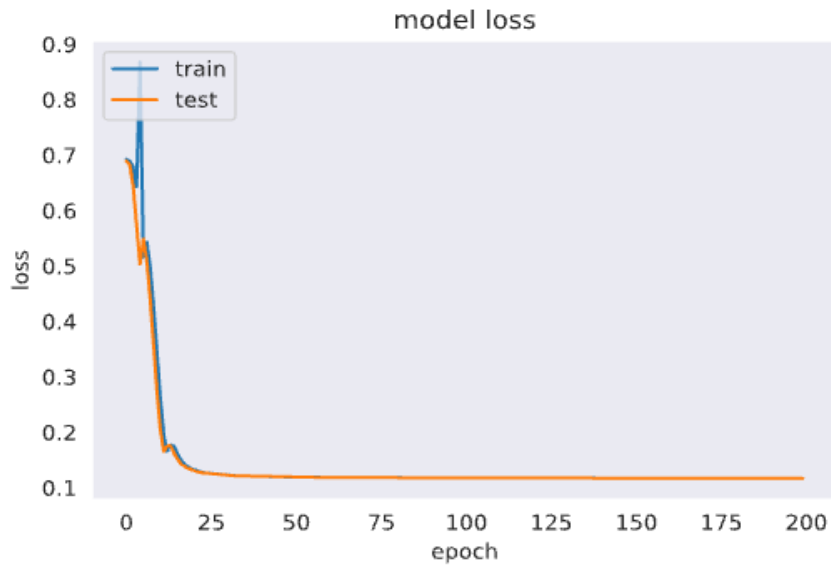


Figure 3: The above image shows the model loss of our trained VAE. Model loss = latent loss + reconstruction loss. Reconstruction loss is the loss that is experienced when rebuilding the image and latent loss is the loss that is experienced by the latent space.

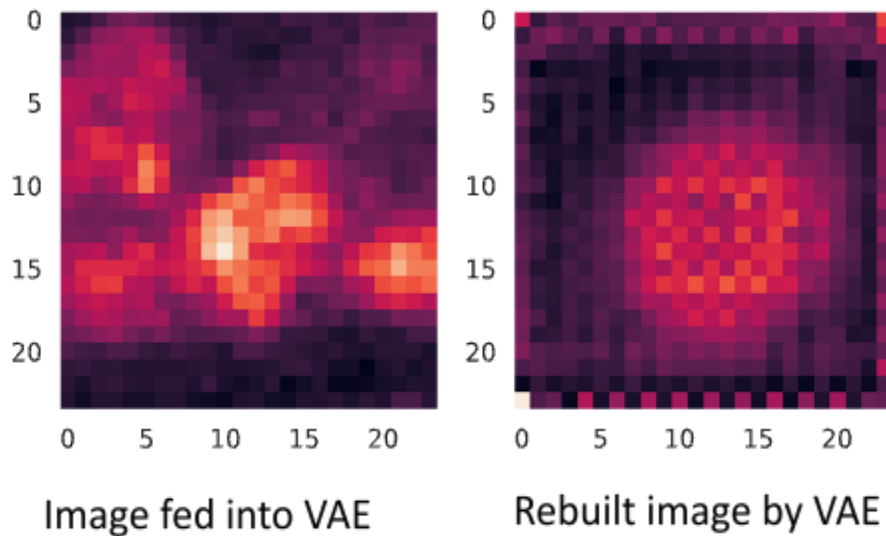


Figure 4: The quality of the rebuilt image shows the disadvantage to only using 2 latent vectors to represent the entire 24x24 image.

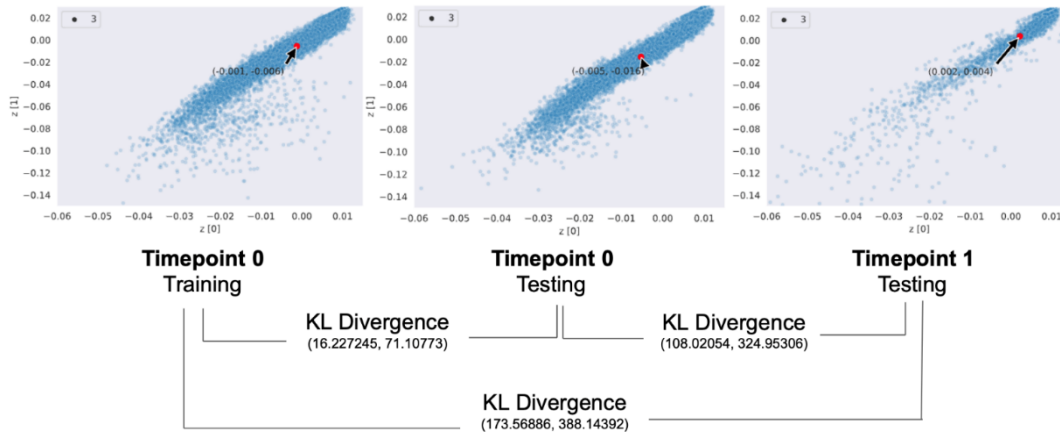


Figure 5: The larger KL Divergences for the comparisons *between* timepoints than those *within* a timepoint suggests that the VAE is learning the patient’s baseline tumor phenotype.

## Discussion

This work shows the feasibility of using an automated pipeline to create a personalized VAE that can detect tumor divergence during a patient’s breast cancer treatment course. Future work on this topic should focus on better examining the meaning of the latent space vectors of the VAE and how they relate to patterns across image channels. Many of the shortcomings of this project have to do with sacrificing the quality of the results for interpretability of the results. For example, adding another dimension to the latent vector would have increased the accuracy of the regenerated image but would make it much harder to quantify the difference between two timepoints as the data would be 3 dimensional. Along with that, this project is only able to quantify how much the cancer changed and not if it changed for worse or for better, though this information can be interpreted from the biomarker expression plots. With more analysis of the latent space combined with other analyses performed on the biopsy, it would be possible to better understand how much the cancer changed and why the cancer changed.

## Methods–Data

The Human Tumor Atlas Network (HTAN) open dataset of imaging was accessed on their website. One breast cancer patient with serial biopsies each with CyCIF images available was selected. Imaging data of three biopsies (two at a concurrent time-point and one at a follow-up time-point) for this patient was gathered. Raw CyCIF files were downloaded via the Google cloud command line interface (gCloud CLI). All the files were downloaded in DICOM format, the common file type for medical images. Each DICOM file was a slide of the complete biopsy and represented a different marker.

To run the data through the MCMICRO pipeline, a csv file that contains information on the marker associated with each channel in the DICOM image was necessary. Each DICOM file that was downloaded was associated with a singular marker, so the CSV file was needed to

compile all the different markers that were present in the biopsy. Headers for all the DICOM files that were downloaded were parsed and used to generate a csv file for each biopsy.

### **MCMicro**

Using nextcloud, the MCMICRO pipeline was run on the dataset with the generated csv file. To create training data for the VAE, the segmentation of the dataset that was performed by the MCMICRO pipeline was used to generate small images (24 by 24 pixels) for each of the cells that were found. The image size is 24 x 24 because it was the maximum size of any given cell that was segmented so it would for sure capture each of the cells that were segmented. The data was then saved into a numpy array.

### **VAE**

The Variational Auto-Encoder was created using Keras, a neural network library. The model that was created has 4 2D convolutional layers, 2 dense layers, 1 flatten layer, and 1 2D Convolutional up sampling layer. To train the model, saved data was loaded in the form of a numpy array and then partitioned so that 75% of the data stored in the file was used for training while the other 25% was used for testing.

The VAE was trained on one biopsy from one time point and tested on held out test data from the same biopsy/time point, a different biopsy at the same time point, and a different biopsy at a later time point, The latent vectors of each run were visualized and used to quantify how much the cancer changed. The KL divergence statistic was used to quantify the difference in the probability distributions.

### **Conclusion**

This project applied a Deep Learning-based segmentation module to quantify tumor marker expression in breast cancer molecular imaging over time as a patient underwent breast cancer treatment. A VAE trained on baseline data showed that it was able to track and quantify the differences in single-cell expression over time. Future research on this topic should focus on validating this pipeline in multiple other subjects who have serial biopsies and better understanding the implications in tumor progression from the latent space changes.

### **Acknowledgments**

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## Works Cited

- Wu, F. *et al.* Single-cell profiling of tumor heterogeneity and the microenvironment in advanced non-small cell lung cancer. *Nat. Commun.* **12**, 2540 (2021).
- Breast Cancer Hormone Receptor Status | Estrogen Receptor.  
<https://www.cancer.org/cancer/types/breast-cancer/understanding-a-breast-cancer-diagnosis/breast-cancer-hormone-receptor-status.html>.
- Estrogen Receptor, Progesterone Receptor Tests: MedlinePlus Medical Test.  
<https://medlineplus.gov/lab-tests/estrogen-receptor-progesterone-receptor-tests/>.
- Gupta, R. K. & Kuznicki, J. Biological and Medical Importance of Cellular Heterogeneity Deciphered by Single-Cell RNA Sequencing. *Cells* **9**, 1751 (2020).
- Li, A. *et al.* Characterizing advanced breast cancer heterogeneity and treatment resistance through serial biopsies and comprehensive analytics. *Npj Precis. Oncol.* **5**, 1–12 (2021).
- Lin, J.-R., Fallahi-Sichani, M., Chen, J.-Y. & Sorger, P. K. Cyclic Immunofluorescence (CycIF), A Highly Multiplexed Method for Single-cell Imaging. *Curr. Protoc. Chem. Biol.* **8**, 251–264 (2016).
- Basu, K., Sinha, R., Ong, A. & Basu, T. Artificial Intelligence: How is It Changing Medical Sciences and Its Future? *Indian J. Dermatol.* **65**, 365–370 (2020).
- Cheung, A. M.-Y. *et al.* Quantitative single-cell analysis of immunofluorescence protein multiplex images illustrates biomarker spatial heterogeneity within breast cancer subtypes. *Breast Cancer Res.* **23**, 114 (2021).

# **A Correlational Study: The Relationship Between TikTok Usage, Perceived Academic Performance and Social Life of High School Students at University Hill Secondary By Jisoo Choi**

## **Abstract**

TikTok is a digital content creation platform where users can upload videos on various topics. These videos range between 30 seconds and 3 minutes in length, which has shown to greatly appeal to its audiences. On TikTok, users are able to socialize in the comfort of their home anonymously and independently. Although it has been beneficial in entertaining and maintaining social life online especially through the pandemic, the concerns of how TikTok affects student's educational outcomes and social wellbeing has risen. Therefore, this research paper aims to examine how the usage of social media platform, TikTok, can affect academic performance and the social lives of high school students in Canada. Using convenience sampling, 30 students were recruited from University Hill Secondary situated in Vancouver, British Columbia to complete the Social Media Addiction Scale - student form (SMAS-SF).

## **Introduction**

After the rise of the pandemic, social media has become a predominant part of an individual's life. Especially amongst the younger population, it has become a common way to bring these students together despite their failings such as low satisfaction with social relationships and self-esteem in real life (Hawi and Samaha 576). TikTok in particular has become increasingly popular since 2020 amongst the younger age group. It has over 1 billion monthly users who actively use the app, and 63% of them have been shown to be between ages 10-29 in 2021 (Mansoor 11). From the simple design and user prioritized algorithm to the conveniently short videos that give users a constant rush of dopamine with every scroll on TikTok encourages and attracts young people into spending a lot of time on the app.

According to Next Gen Personal Finance, the average user spends 91 minutes per day on TikTok, taking 21.5 hours of time from one month (Wood). Studies on the social media addiction arising has shown that those with lower self esteem are more likely to use more social media sources as an attempt to boost their self image and improve self esteem (Hawi and Samaha). Furthermore, there is a significant positive correlation between academic achievement and self esteem amongst university students (Muhammad et al. 161). This can explain the addictive nature of social media especially amongst students whose self-esteem are heavily impacted by their level of academic achievement. When grades start to drop so does a student's self esteem, making them more vulnerable to social media addiction. Several people including students with low self esteem, low life satisfaction, and limited real life relationships use certain forms of social media such as facebook as a way to make up for their paucity of social life by creating friends and gaining followers online (Hawi and Samaha; Arshad Muhammad et al. 161). Social media can also be a way for friends and families to keep in touch which can especially be important amongst students who want to maintain relationships after graduation. Overall, there

are many different factors, some beneficial and some unhealthy, that play into the addiction of social media especially for students.

Previous studies on social media and academics have shown how social connections made from social media can improve relationships at school, learning motivation, and participation (Al-Rahmi & Othman 1). However, some studies have also shown that TikTok can have a negative impact on the attention span of students during classes due to the app serving as a distraction which can overall be harmful to their education (Mekler 146). Wang's college study has shown that although social media has a clear effect on college academics, it can be both beneficial and harmful depending on the usage. It has been shown that social media can act as a way to release the pressure on students from grades, and it can also have negative impacts on grades if there isn't a balance between social media use and academic study (Wang et al. 9). When this balance is broken and social media is overused, there is a poor influence on academic performance (Al-Rahmi & Othman 6). However, some studies have also shown that there is no significant relationship between social media usage and academic performance (Al-Rahmi & Othman 6). Therefore, the purpose of this research is to determine if the effects of the addictive nature of TikTok can influence academic performance of high school students and examine how the usage affects perception of social relationships in adolescents.

Based on the literature review, it is hypothesized that higher perceived reliance on TikTok may influence motivation levels of students which may in turn adversely affect their academic performance. Moreover, the number of hours spent on social media may be linked to a lower quality of time spent with friends and family in real life. This may lead to lower satisfaction in relationships and higher levels of social media usage.

## **Methodology**

This survey is targeted towards University Hill Secondary school students. Out of 1000 students, 29 students, from ages 16-18, were selected as subjects through convenience sampling. Participants consisted of females and males with a majority of them being females. Participants were approached on the basis of convenience sampling and given a link to an online google forms survey through social media platforms such as Instagram and Discord. The link, followed by a brief summary of the purpose of the research study, was sent to each participant. The survey used is the Social Media Addiction Scale - student form (SMAS-SF) that was modified to fit the research focus of this paper.

The Social Media Addiction Scale - Student Form (Sahin 179) was employed to assess TikTok addiction and their effects in this study and modified slightly to have the questions directed towards TikTok specifically instead of social media as a whole. The validity of the content on whether the SMAF-FS was able to measure social media addiction was proven by experts in the fields of psychological counseling and guidance, psychiatry, computer and instructional technology, measurement and evaluation, and Turkish language education (Sahin 172). The experts were given a 3-point rating form to express their opinions on the form by marking each component of the survey as either "appropriate", "partially appropriate", or "not



suitable” (Sahin 172). Although some parts of the survey was removed from the scale and adjusted to be more efficient, the content validity of this survey overall was proven by experts from various fields related to the area of study with the addition of several student opinions, information from previous literature, and literature experts (Sahin 172). The construct validity of the SMAF-FS, which is how fitting the data obtained from the survey for factor analysis, was confirmed through the Kaiser Meyer Olkin (KMO) and Bartlett test (Sahin 172). The reliability of the scale of the SMAF-FS was determined through a series of analyses on the internal consistency levels and the stability level of the paper which overall showed a high reliability (Sahin 177-178). Through the help of expert opinion, statistical tests, and reliability analysis the SMAF-FS was proven as a valid and reliable measurement of social media addiction.

### Analysis and results

After the data collection, the basic demographics of the participants in this research study was analyzed. 79.3% of the participants were female while 17.2% of the participants were male and 3.4% described themselves as other. While the study was conducted on students ranging from ages 15 to 18 (grades 10-12), a majority of the sample was between ages 16 and 17. 44.8% of participants reported to go on TikTok over 4 times a week. However, 37.9% of participants never went on TikTok. Although, most of the questions from the survey were included in our correlational analysis. However, questions 5, 11, 14, 16, 17 were excluded from the analysis because the extent of TikTok usage is likely proportional to the importance it has in participant’s lives.

Questions 2, 3, 12, 21, 24 show the extent of TikTok usage of each student. Questions 15, 22, and 28 from the modified SMAF-FS questionnaire measured perceived academic performance while questions 6, 7, 8, 10, 13, 19, 26, 27, 29 were used to represent social life. Questions 2, 3, and 12 showed a positive correlation with the questions signifying a negative influence on academic performance between the ranges of 0.4 to 0.8. The amount of time participants spent on Tik Tok alone showed the strongest positive correlation of 0.785 with diminished perceived productivity.

**Table 1: Social media usage and perceived impact on academic performance correlation**

	<i>Q2</i>	<i>Q3</i>	<i>Q12</i>	<i>Q21</i>	<i>Q24</i>
Q15	<b>0.484</b>	<b>0.518</b>	<b>0.661</b>	-0.034	-0.066
Q22	<b>0.486</b>	<b>0.417</b>	<b>0.785</b>	-0.032	0.222
Q28	0.257	<b>0.417</b>	<b>0.532</b>	-0.031.	<b>0.408</b>

In terms of perceived impact on social life, questions 2, 3, 12, and 24 all showed moderate to strong correlation. The highest correlation coefficient was found with the amount of

time participants spend on TikTok and participants' preference to spending time on TikTok even if there's somebody around them. The time on TikTok when participants were alone overall had the most correlation with the questions surrounding both perceived academic performance and social life. Participants' inability to notice when they are hungry and thirsty when they are on TikTok on the other hand showed the weakest correlation coefficient in comparison to the other questions.

**Table 2: Social media usage and perceived impact on social life impact correlation**

	<i>Q2</i>	<i>Q3</i>	<i>Q12</i>	<i>Q21</i>	<i>Q24</i>
Q6	0.217	<b>0.418</b>	<b>0.801</b>	0.151	<b>0.540</b>
Q7	-0.147	-0.086	-0.053	-0.060	-0.049
Q8	0.195	-0.086	0.087	-0.060	-0.049
Q10	0.042	-0.155	-0.012	-0.108	-0.087
Q13	0.071	0.042	0.390	0.082	-0.147
Q19	<b>0.440</b>	<b>0.525</b>	<b>0.600</b>	-0.046	-0.110
Q26	0.371	0.097	<b>0.672</b>	0.228	0.301
Q27	0.342	0.110	<b>0.576</b>	0.156	0.318
Q29	0.284	0.141	<b>0.530</b>	0.054	-0.017

### Discussion

This experiment was conducted to determine the relationship between TikTok usage, perceived academic performance and social life of high school students. It was hypothesized that there is a negative correlation between TikTok usage and perceived academic performance and social life. The results of this study validated the hypothesis by showing a positive relationship between TikTok usage and adverse effects on perceived academic performance and social life.

The results of this study demonstrates that there is a notable negative correlation between the variables of the study. The analysis shows that there is a considerable amount of positive correlation between TikTok usage and poor academic performance and social life. Therefore, the results of the survey shows a negative correlation between TikTok usage and academic performance and social life. The especially high correlation coefficient between the desire to spend time on TikTok when the participant is alone and the preference to use TikTok even when there is somebody around shows how extensive use of TikTok can potentially lead to less social interactions amongst peers. Being that the desire to spend time on Tik \Tok alone showed the most correlation with both the questions related to academic performance and social life, it can overall be concluded that the increased likelihood of spending more time on TikTok is greatly

associated with adverse effects on perceived academic performance and social life. The desire to spend time on TikTok when the participant is alone also shows moderate correlation with the amount of time participants spend on Tik Tok to see special announcements like birthdays and to be instantly informed about what their kith and kin share. Although there is a considerable correlation, a clear conclusion cannot be made here as the extensive usage of Tik Tok is being correlated with actions on TikTok that have positive effects on social life. It should also be noted that the participants' inability to perceive hunger and thirst when they are on TikTok showed the weakest correlation to all the questions surrounding academic performance and social life. This can imply that there are certain extents to TikTok usage where there is not a significant connection to decreased or increased perceived academic performance and social life.

Although a significant correlation was found, limitations of the study should also be considered when looking at the results. A major limitation of this study is the small sample size of only 29 students that were predominantly female which makes the representation of the population of University Hill Secondary less accurate. The big gender gap may have allowed gender differences to interfere with the results of the study. Furthermore, the sample size for analysis is even smaller as nearly 40% of the participants do not use Tik Tok, meaning that 40% of the sample results are not a part of the analysis. Another limitation is that this study only measured perceived academic performance and social life, not actual tangible evidence of the academic performances and social lives of the students.

Due to the limitations mentioned above, future studies should be done to determine a clear cause and effect relationship that can be generalized to a greater population. Based on the findings of this research, there is a significant correlation between TikTok usage, academic performance, and social life that should be explored further. It should also be noted that the study found such results with a predominantly female sample. Further exploration can be done to determine whether there is a significant gender difference that influences the relationship of the two variables. As TikTok's audience continues to grow, having extended research done on this topic that goes beyond correlational analysis as well can be an extremely beneficial step. Thus, having future studies done that conducts experimental methods on a much wider population to find a cause and effect relationship between the variables of this study can be a very valuable source of research that has the potential to heavily impact the social wellness and education of many adolescents in high school.

## Appendix - Social Media Addiction Scale

Likert scale of 1 (strongly disagree) - 5 (strongly agree)

1. I am eager to go on Tiktok.
2. I look for internet connectivity everywhere so I can go on Tiktok.
3. Going on Tiktok is the first thing I do when I wake up in the morning.
4. I see Tik tok as an escape from the real world.
5. A life without Tik tok becomes meaningless for me.
6. I prefer to use Tik tok even if there is somebody around me.
7. I prefer the friendships on Tiktok to the friendships in real life.
8. I express myself better to the people with whom I get in contact on Tiktok.
9. I am as I want to be on Tiktok.
10. I usually prefer to communicate with people via Tiktok
11. Even if my family frown upon, I cannot give up using Tiktok
12. I want to spend time on Tik tok when I am alone
13. I prefer virtual communication on Tiktok to going out
14. Tiktok activities lay hold on my everyday life
15. I pass over my homework because I spend much time on Tiktok
16. I feel bad if I am obliged to decrease the time I spend on Tiktok
17. I feel unhappy when I am not on Tiktok
18. Being on Tiktok excites me
19. I use Tiktok so frequently that I fall afoul of my family
20. The mysterious world of Tik tok always captivates me
21. I do not even notice that I am hungry and thirsty when I am on Tiktok.
22. I notice that my productivity has diminished due to Tiktok
23. I have physical problems because of Tik tok use
24. I use Tik tok even when walking on the road in order to be instantly informed about developments
25. I like using Tiktok to keep informed about what happens
26. I surf on Tiktok to keep informed about what Tiktok accounts share
27. I spend more time on Tiktok to see some special announcements (eg. birthdays)
28. Keeping informed about the things related to my courses (eg. homework, activities) makes me always stay on Tiktok
29. I am always active on Tiktok to be instantly informed about what my kith and kin share

### Works Cited

- Arshad, Muhammad, Syed Muhammad Imran Haider Zaidi, and Khalid Mahmood. "Self-Esteem & Academic Performance among University Students." *Journal of education and practice* 6.1 (2015): 156-162.
- Al-Rahmi, Waleed Mugahed, and Mohd Shahizan Othman. "The Impact of Social Media use on Academic Performance among university students: A Pilot Study." *Journal of Information Systems Research And Innovation*, (2021): 1-10
- Hawi, Nazir S., and Maya Samaha. "The Relations among Social Media Addiction, Self-Esteem, and Life Satisfaction in University Students." *Social Science Computer Review*, vol. 35, no. 5, 2016, pp. 576–586, <https://doi.org/10.1177/08944393166660340>.
- Iqbal, Mansoor. "TikTok revenue and usage statistics (2021)." *Business of apps* 1.1 (2021).
- Mekler, Audrey. The Effects of TikTok Use on College Student Learning. *Undergraduate Review*, 16, 145-153 (2021).
- Sahin, Cengiz. "Social media addiction scale-student form: the reliability and validity study." *Turkish Online Journal of Educational Technology-TOJET* 17.1 (2018): 169-182.
- Wang, Qingya; Chen, Wei; and Liang, Yu, "The Effects of Social Media on College Students" (2011). *MBA Student Scholarship*. Paper 5. [http://scholarsarchive.jwu.edu/mba\\_student/5](http://scholarsarchive.jwu.edu/mba_student/5)
- Wood, Ryan. *Qod: How Long Does the Average User Spend on TikTok a Day? - Blog*, Next Gen Personal Finance, 28 Mar. 2023, [www.ngpf.org/blog/question-of-the-day/question-of-the-](http://www.ngpf.org/blog/question-of-the-day/question-of-the-)

# **The Organism: Connectivity, Isolation, and the Shifting Territories of the Digital Age By Tyler Shaver**

## **Abstract**

This paper delves into the profound transformations brought about by the advent of the digital age, marked by the emergence of "the organism." Drawing upon Deleuze's notion of the transition from disciplinary societies to societies of control, the concept of rhizomatic structures, and ideas surrounding schizophrenia, the paper explores how the organism, a complex web of interconnected devices and data centers, has reshaped human communication, knowledge acquisition, and societal structures. It highlights the paradox of increased global interconnectivity coexisting with heightened feelings of isolation. The paper also addresses the influence of capitalism on the organism, notably through datafication and the centralization of user data. Furthermore, it discusses how individuals with ADHD are now ideal participants in this digital ecosystem, leading to both the idealization and resistance of ADHD within the organism. Finally, the paper touches upon the Deleuzian concept of the "Body without Organs" to analyze the organism's impact on human society and the blurring of boundaries between the physical and digital worlds. As our world continues to be reterritorialized by the organism, it sets the stage for further societal transformations and challenges.

## **Introduction**

In the 1970s, Foucault made an argument that we live in the age of discipline. It is characterized by hierarchical observation, punishment, and authoritarianism (Foucault, "Discipline and Punish" 170). In this society, one graduates from the bottom of one closed environment to another. One graduates from school as a student, and enters the workforce as a worker, then enters the prison as a prisoner or the hospital as a patient (Foucault, "Madness and Civilization" 160-161). In the 1990s, Deleuze argues that we have passed the age of discipline and are in the age of control. The hierarchical observation and authoritarianism have been replaced by datafication and tracking (Deleuze, "Postscripts on Societies of Control" 3). As society has broken definitions and boundaries regarding gender, sexuality, race, mental illness, politics, and almost every facet of human life, we blur what things mean, and destroy them. Instead of graduating from one closed environment to another, we have decimated the barriers encapsulating these closed environments. One now works during school, retires during work, is a hospital patient while in prison, and constantly shifts between these now-open environments. Because the closed environment's walls have been crumbled, they are absorbed into one, large, and open multiplicity. This change can be seen through the evolution of video games. In the 80s and 90s, one would play a game of Mario where the player begins at the start of every level, and graduates to the next level periodically. Now, one plays Call of Duty online with people throughout the world. There is no objective end in sight and no graduation to the next level. A player moves throughout the open environment of Call of Duty without completion. Furthermore, players are datafied by the number of kills, deaths, and victories they achieve and

are systematically ranked by “level” based on these achievements. The evolution of video games is an analogy for the shift that occurred from the end of the 20th century into the modern day.

This shift has worked in tandem with the rise of technology in the digital age. As technology pervades humanity, humanity becomes reliant on technology. Through the reliance on technology, a new being emerges, the organism. The organism is a mediator for humanity, while humans use the organism to interact with one another, humans become reliant on the organism to interact with one another. This poses a paradox that the digital era has been plagued with. On one hand, humans are more interconnected than ever before. In an instance, a human in the US can talk to a human in India. Constantly, without even thinking about it, we have communicated through social media with everyone across the globe. On the other hand, humans have felt more isolated now than ever. This is because, while humans have the ability to connect with any human, they are forced to connect with everybody through the organism. A human must communicate directly with the organism to communicate indirectly with another person. This establishes a superficiality to human communication and a barrier that does not allow humans to directly communicate with each other.

Not only does the organism alter the communication between humans, but it reshapes every aspect of humanity through constant deterritorialization and reterritorialization. Instead of learning from books, we learn from YouTube videos, documentaries, and digital content. Instead of using physical maps, we use Google Maps. Furthermore, the organism reterritorializes to make humanity reliant on the organism. We are reliant on iPhones to communicate with one another, digital GPS for transportation, and laptops to work. Whereas before paper and pencil was the sole device for writing, the organism replaced it with laptops and phones. We have replaced the individuality of paper and pencil with interconnectivity through the organism. The organism, emerging from our reliance on technology, engenders a complex interplay between connectivity and isolation in the digital age. Through the dynamic processes of reterritorialization and deterritorialization, it actively shapes the digital landscape, blurring traditional boundaries, and assumes the role of an intermediary in human interactions. This multifaceted influence extends to communication, information sharing, and self-presentation, redefining social norms, identity formation, and economic structures in our increasingly interconnected world.

## **The Technological Entity: An Open, Living Organism**

### *Characteristics of the Organism*

The organism exhibits an open and dynamic structure, embodying a multiplicity of interconnected devices and data centers, forming the physical foundation of its existence. There is no structural form or arborescent nature to the organism. Instead, the organism is completely rhizomatic, flowing freely from one sector of humanity to another. First, there was the Macintosh (1984), then the iPod (2001), then the iPhone (2007), which are linear developments. Next is Airplay (2010), AirPods (2016), Apple Homekit (2014), Apple Music (2015), Apple Pay (2014),

and Apple Maps (2012). Apple expanded rhizomatically, to new territories that had been untouched.

Furthermore, every Apple device is interconnected; the iPhone connects with AirPods to play Apple Music which can be bought with Apple Pay. Interconnection is not solely within companies, but between companies as well. Located on the iPhone is Google Drive which shares files with the Windows Laptop that can be printed on a printer. One task, printing a photo taken on a phone, takes a multiplicity of interconnected devices, and thus separate companies. Technology, such as Bluetooth, is created for the sole purpose of interconnecting one entity to another, creating a homogenous multiplicity. This interconnectedness has slowly reterritorialized human communication. In 2023, there were 5.81 billion internet users worldwide, which is 60% of the global population (Petrosyan). These people could access over 55 million Wikipedia articles, which are available in over 300 languages (Wikimedia Foundation). Once inside a Wikipedia page, one could click an internal hyperlink, connecting that very user to another side of the organism. If one were to find a humorous article, one could send it to another person via one of the 23 billion globally connected devices (Taylor). While the organism is vast and encompasses all sides of human life, one can teleport from one sector of the multiplicity to another in an instant.

Additionally, the physical foundation of devices connects the digital world to the material world. From another angle, rapid progression and expansion in both the digital and material worlds flow from the device. It is the device, which connects two separate lands, that interconnects every human, company, and object instantaneously.

Tapping into the organism creates both enhanced connectivity and barriers to human interaction, as evidenced by studies revealing the isolating effects of excessive social media and smartphone reliance. Every day, we are introduced to strangers and reconnected with acquaintances through social media. We physically see each other constantly and communicate with each other at a rate never seen before. When before, one had to write and mail a letter, now that very same person can text. It would be rational to assume that humans would feel more connected than ever before because of the extreme expansion of technology, yet humans are more isolated than ever before. This is because, now, humanity is reliant on the organism to communicate. There is no other option aside from texting, emailing, or calling. A human must tap into a device, a third entity, teleporting inside the digital world, to indirectly connect with another human. To connect indirectly with another human, one must connect directly to their device. There is no face-to-face interaction, only phone-to-phone. Humanity became reliant on the organism to communicate. According to the Journal of Social and Clinical Psychology, spending more than 30 minutes per day on social media platforms is correlated with increased feelings of loneliness and depression (Liu M). Teenagers who use technology multiple times daily have higher chances of obesity, attention span, and overall well-being (Rosen LD). With 1 billion active users on Instagram and 2.8 active users on Facebook worldwide, the constant and consistent interaction with the organism is what creates a dynamic, rhizomatic structure that indefinitely reterritorialization. It is an entity of constant becoming through the repetition, in the



Deleuzian sense, of tapping into the organism, which endlessly expands the digital and material worlds.

### *Interconnectedness and the Role of the Internet*

Examples of interconnectedness, such as the presence of hyperlinks on platforms like Wikipedia, foster a web of interconnected knowledge, enabling seamless navigation between diverse topics. As stated previously, Wikipedia exemplifies interconnection inside a structure, between structures, and between humans. Wikipedia, itself a structure, is interconnected through hyperlinks within an article that sends the user to another article. There is no escape from Wikipedia's open structure. One is constantly teleported to a new area within Wikipedia, which allegorically connects to how there is no escape from the open structure in societies of control (Deleuze, "Postscripts on Societies of Control" 3-5). Wikipedia also acts as a connector, connecting two structures. It is the hyperlink that connects Berlin to Germany within a Wikipedia article. While this is a simple example of connectivity as a hyperlink to Germany can be found within the article on Berlin (and vice versa), every single article is interconnected, through hyperlinks, to every other article. These articles act as the digital representation of the physical entity. Even though the article is a digital representation, it is still found within the concept that contains both digital and physical representations (ie: the concept of Berlin is found both within the city of Berlin itself and the Wikipedia article representing Berlin). The hyperlinks, thus, have two roles, one as a structure itself and another as a connector between two structures. This digitizes knowledge, forcing a human to tap into the organism to access information. This mass digitization of information is not the only thing that reinforces connectivity.

The internet, serving as a medium for connectivity, also reinforces reliance on the organism as indicated by the global reach and influence of platforms like Facebook, Instagram, and YouTube. As Zuboff mentions in *The Age of Surveillance Capitalism*, companies carefully curate a monopoly over the digital world. In 2006, Google paid \$1.65 billion for YouTube which, at the time, had never made any money. The reason was that "it ensures millions and millions of viewers are coming to a Google-owned site rather than someone's else's site," (Zuboff 73). Companies ensure there is no escape from the organism. One is forced to interact with the organism. While having no escape helps reinforce reliance on the organism, companies also must ensure that consumers keep returning. This is why, when Eric Schmidt, CEO of Google, was asked about why Google had 150 products, Eric responded by stating that Google had only 1 product, "customer satisfaction". Technological platforms owned by monopolies simultaneously limit all competition while giving consumers enough satisfaction to continue using these sites. This provides a stable foundation for the organism to spread throughout society.

### **Capitalism's Impact on the Organism**

Capitalism significantly influences the organism through the process of deterritorialization and reterritorialization. Throughout history, music has been a communal activity. Music was indulged by the masses. Groups of humans went to mass, and symphonic

halls, or danced to music outside. This all changed with the development of records, vinyls, walkmans, and iPods. At first, the music industry expanded rapidly because of the new-found accessibility. As more people began using these devices to listen, the organism rapidly reterritorialized the music industry so that consumers became reliant on the organism. Now, music is a deeply intimate and personal activity. Now when someone is listening to music, they are often not communicating with others or in a group of people. In the first quarter of 2021, Spotify had over 356 million monthly active users worldwide (Gotting). Now, artists' are reliant on the organism to advertise their music and consumers are reliant on the organism to consume music (McPherson and Welch, 212; McKay et al, 7). Before, there was a direct connection between the artist and the audience through symphony centers, whereas, through the reterritorialization of the music industry, there is an indirect connection between the artist and the audience because the organism acts as an intermediary. Similar examples are also found with the rise of Amazon and online markets or the rise of Netflix and cinema. Furthermore, these companies act without an end in sight. This is why companies rely on never-ending subscription services (Spotify Premium, Amazon Prime, Netflix). The organism is not restricted to the confines of space or time, stretching infinitely across digital worlds forever.

### **Singularity and Datafication**

Capitalism's influence manifests in the singularity of the organism, where data collection and analysis become central, evident in the prevalent collection of user data and the growing awareness of online tracking. To continue customer satisfaction, reliance, rapid expansion, and capital growth, the organism is reliant on data collection. Because of the constant interaction with the organism with no escape, the organism, in turn, collects data through these interactions. By searching a question in Google, the question is logged, saved, sold, and used by an advertising service to target an advertisement to the user. 72% of Americans feel that most or all of what they do online is being tracked by companies, and 67% of consumers are willing to share their personal information with companies if it leads to personalized offers or discounts (Auxier). This is where the organism transforms from a multiplicity of corporations into a singularity. These corporations are forcibly intertwined by sharing information about each user. It is a win-win situation for the corporations: I get more information on the user and, in exchange, you get more information on the user. Thus, the organism is centralized, and solidified into one, through online tracking. All of the moving parts within the organism work together to force users to become reliant, give users enough satisfaction to return, and then sell users to advertising agencies.

The implications of datafication encompass individual agency, privacy concerns, and the amplification of capitalist systems, reflected in the willingness of consumers to share personal information in exchange for personalized offers. Consumers want to share their personal information if it grants more efficiency and more money. In return, individuals lose their individuality. Users are datafied and objectified by their digital history. Next, users are followed. Tracking is a temporal activity that attempts to understand a person over time. By constantly

tracking users relentlessly, companies understand private information. Finally, this private information is sold to advertisers, expanding the capitalist system. Capitalism is reliant on the constant trade of goods and services. In this context, the capitalist system is amplified by reterritorializing the human and transforming the human from a person to an object. The implications of datafication are the buying and selling of humans (their attention, personal information, etc). In a twisted fate, the system that was marketed as more humane and a better alternative than the buying and selling of humans through slavery (to work) has developed into the buying and selling of humans (their attention).

### **ADHD: The Ideal Human yet the New Schizo**

The constant connectivity and information overload of the organism renders individuals with ADHD as ideal participants in this digital ecosystem. The organism hijacks the eccentric, ADHD mind. Or, the organism creates ADHD (eccentricity, schizophrenic) to hijack individuals. ADHD becomes a part of the organism, interconnected within the multiplicity. The mind is absorbed. The constant flow of information, the flow of the organism, feeds ADHD. And so does ADHD flow into the organism, exchanging content for attention. As Mark Fisher wrote in *Capitalist Realism*, ADHD was “a pathology of late capitalism - a consequence of being wired into the entertainment control circuits of hypermediated consumer culture,” (Fisher, 25). Furthermore, the individual with ADHD is constantly reterritorializing its surroundings, a constant shift and perpetual flux. Thus, the organism’s constant reterritorialization connects with and expands upon the reterritorialization found within ADHD. ADHD, in this case, is not a disorder, but the ideal human in a society overtaken by the organism. ADHD is order. ADHD becomes the exemplar. Pharmaceutical companies make millions off of the treatment of ADHD, further incentivizing an individual to be diagnosed. The organism profits off of this manipulation.

However, ADHD also becomes the enemy. In this sense, ADHD is the trojan horse to the organism (Basu). ADHD integrates itself and slowly changes the foundation of capitalism within. The ADHD resists conformity to society, questioning the rigid structures held at the foundation of capitalism. As an example, in school, ADHD receives accommodation (extra time on tests, an iPad to type if they have dysgraphia). These accommodations attack the rigid structure of the school which is meant to teach students how to fit within the capitalist society. How do we teach students how to listen, when, through accommodations, the teacher is forced to listen? These practices flow into the workplace. Many people with ADHD challenge the traditional 9-5 office culture and advocate working remotely. These practices are not even gatekept by those with ADHD. Now, many people, including people without ADHD, advocate for these practices. ADHD forces diversity, as workplaces are forced to welcome neurodivergence into the office. While more people become diagnosed with ADHD, more offices have to accommodate them. Finally, the ADHD does not produce, it consumes. To produce is typical and old-fashioned, whereas to consume is new. It consumes. It consumes content fed by

the organism, thus breaking the cycle of production required for late-stage capitalism. Who is there to produce when the organism incentivizes constant consumption?

### **The Organism as a Body without Organs: Analysis of Rhizomatic Territorialization**

Deleuze's concept of the "Body without Organs" finds relevance in understanding the organism, as it encompasses the exploration of reterritorialization and deterritorialization within power structures and territories, providing insight into the organism's dynamics. The organism is a Body without Organs. It is constantly and rhizomatically creating new connections and possibilities because of its lack of structure. This lack of structure, however, is what makes it so different from anything the world has seen. No innovative technology has rapidly changed the world like how the digital age has. Due to its lack of structure and organization, the organism can adapt to all environments, deterritorializing them by absorption. It is similar to cancer that rapidly spreads, without end in sight, through the body. It corrupts and alters the foundation of structures as cancer corrupts the cells of a body. It has even shifted the very nature of capitalism. Where before capitalism hierarchically ordered humans into creating a good to be bought, humans are now the good being bought. There is no need for a hierarchically structured workforce with the implementation of artificial intelligence. Instead, capitalism becomes rhizomatic to facilitate the purchasing of human attention on a mass scale. Attention is constantly moving within the open structure of the organism which is used for the profit of companies. The emergence of creativity that Deleuze envisioned would come in a rhizomatic society is being tracked and used for targeted advertisement. Capitalism reterritorialized capitalism, transforming the previously closed, hierarchical structure into an open, rhizomatic structure. While the former capitalism is forced to establish hierarchies to control humans into being producers, the latter forces humanity into a position of constant consumption. Additionally, it is the personal information humans are willing to give to consume that is bought and purchased which continues capitalism.

The extension of the line of flight signifies the organism's expansive influence, demonstrated by the global dependence on the internet for various activities, leading to significant societal transformations. Currently, the organism is making the shift in our world that pushes humanity past structures and boundaries. As the organism continues to constantly deterritorialize as a Body without Organs, society as a whole will follow suit due to the rise in global dependency on the organism. Furthermore, the deterritorialization and reterritorialization processes of the organism shape human experiences, societies, and the plane of consistency, shedding light on the societal implications of digital technology. An example of this effect could be the ideas surrounding simulacra, simulation, and hyperreality presented by Baudrillard. Simulation continues to expand through the rapid development of the organism. In addition, hyperreality can be characterized by reliance on the organism. As humanity becomes reliant on the organism, which continually corrupts simulacra and simulation through rhizomatic expansion and reterritorialization, humans further blur the line between what is simulacra and what is simulation. Because of the organism's rhizomatic nature, the lack of structure can be confusing

for humans. Furthermore, the organism as a mediator between human connections causes isolation. Finally, as humans become more reliant on the organism and the digital world, humanity becomes detached from the physical world.

### **Conclusion**

The shift from the age of discipline to the age of control, facilitated by the organism, has brought forth significant transformations in human society. The interconnected and rhizomatic nature of the organism has reshaped communication, knowledge acquisition, and societal structures. It highlights the paradoxical effects of increased connectivity, leading to both global interconnectivity and feelings of isolation. Reliance on the organism as a mediator has blurred traditional boundaries and redefined social norms. Capitalism's influence is evident in the commodification of personal information and the reterritorialization of industries. The organism's impact extends to various aspects of human life, including communication, knowledge dissemination, and self-presentation. Furthermore, it places humanity in a state of constant consumption. Humans are forced to consume in order to keep the organism alive.

In conclusion, the age of control, embodied by the organism, has brought forth a transformative era. Its interconnected and rhizomatic nature has reshaped society, offering both enhanced connectivity and isolating effects. The reliance on the organism as a mediator has blurred boundaries, redefined norms, and commodified personal information. As we navigate this evolving digital landscape, further societal transformations and challenges await.

## Works Cited

- McKay, George & Higham, Ben. (2012). Community Music: History and Current Practice, its Constructions of "Community", Digital Turns and Future Soundings. 10.13140/RG.2.2.26043.03369.
- McPherson, Gary E., and Graham F. Welch (eds), *The Oxford Handbook of Music Education, Volume 2*, Oxford Handbooks (2012; online edn, Oxford Academic, 6 Nov. 2012), <https://doi.org/10.1093/oxfordhb/9780199928019.001.0001>, accessed 1 Aug. 2023.
- Petrosyan, Ani. "Internet and social media users in the world 2023 | Statista". Statista, 22 May. 2023, <https://statista.com/statistics/617136/digital-population-worldwide/>. Accessed 01 August. 2023.
- Foundation, Wikimedia. "Wikimedia Foundation urges Pakistan Telecommunications Authority to restore access to Wikipedia in Pakistan ". Wikimediafoundation, 03 Feb. 2023, <https://wikimediafoundation.org/news/2023/02/03/wikimedia-foundation-urges-pakistan-t-telecommunications-authority-to-restore-access-to-wikipedia-in-pakistan/>. Accessed 01 August. 2023.
- Taylor, Petroc. "Connected devices worldwide 2014-2028 | Statista". Statista, 23 Jun. 2023, <https://statista.com/statistics/512650/worldwide-connected-devices-amount/>. Accessed 01 August. 2023.
- Liu M, Kamper-DeMarco KE, Zhang J, Xiao J, Dong D, Xue P. Time Spent on Social Media and Risk of Depression in Adolescents: A Dose-Response Meta-Analysis. *Int J Environ Res Public Health*. 2022 Apr 24;19(9):5164. doi: 10.3390/ijerph19095164. PMID: 35564559; PMCID: PMC9103874.
- Rosen LD, Lim AF, Felt J, Carrier LM, Cheever NA, Lara-Ruiz JM, Mendoza JS, Rokkum J. Media and technology use predicts ill-being among children, preteens and teenagers independent of the negative health impacts of exercise and eating habits. *Comput Human Behav*. 2014 Jun;35:364-375. doi: 10.1016/j.chb.2014.01.036. PMID: 25717216; PMCID: PMC4338000.
- Zuboff, Shoshana. *The Age of Surveillance Capitalism the Fight for a Human Future at the New Frontier of Power*. PublicAffairs, 2020.
- Deleuze, Gilles. "Postscript on the Societies of Control." October, vol. 59, 1992, pp. 3–7. JSTOR, <http://www.jstor.org/stable/778828>. Accessed 1 Aug. 2023.
- Foucault, Michel, 1926-1984. *Discipline and Punish : the Birth of the Prison*. New York :Pantheon Books, 1977.
- Foucault, Michel. *Madness and Civilization*. Vintage Books, 2006.
- Gotting, Marie Charlotte. "Spotify MAUs worldwide 2023 | Statista". Statista, 16 Jun. 2023, <https://statista.com/statistics/367739/spotify-global-mau/>. Accessed 01 August. 2023.
- Auxier , Brooke, et al. "2. Americans Concerned, Feel Lack of Control over Personal Data Collected by Both Companies and the Government." Pew Research Center: Internet, Science & Tech, 15 Nov. 2019,

[www.pewresearch.org/internet/2019/11/15/americans-concerned-feel-lack-of-control-over-personal-data-collected-by-both-companies-and-the-government/](https://www.pewresearch.org/internet/2019/11/15/americans-concerned-feel-lack-of-control-over-personal-data-collected-by-both-companies-and-the-government/).

Fisher, Mark. *Capitalist Realism: Is There No Alternative?* Zer0 Books, 2022.

Basu, Laura. "Attention Deficit Disorder, the Anticapitalist Condition." *openDemocracy*, 15 May 2022, [www.opendemocracy.net/en/oureconomy/attention-deficit-disorder-anticapitalist/](https://www.opendemocracy.net/en/oureconomy/attention-deficit-disorder-anticapitalist/).

## **The Impact of the 1828 Gold Rush on Brindletown, NC By Lily Wellener**

### **Abstract**

The 1828 Gold Rush in Brindletown, Burke County, North Carolina, unveils a lesser-known aspect of historical events. Beyond the lure of riches and rapid transformation, this narrative uncovers the profound environmental and social impact. Initially a self-sufficient and sustainable community, Brindletown changed drastically with the discovery of gold. The influx of wealthy prospectors and thousands of enslaved individuals enabled extensive mining. Mining methods like sluice boxes and mercury amalgamation caused environmental havoc, with habitat destruction and water pollution. Environmental damage went largely unrecorded due to minimal regulations. The town's economic structure shifted as it became reliant on imports, marking a transition toward capitalism. Ironically, those who transformed Brindletown left for other opportunities. This history challenges the conventional gold rush narrative, emphasizing the exploitation of people and land, environmental harm, and societal transformation. It underscores the intricate interplay between society and the environment, leaving a lasting impact on both. Examining diverse narratives is crucial for a complete understanding of historical events.

### **Introduction**

Mining has long been a cornerstone of human civilization, supplying essential raw materials for countless industries and fueling economic growth. From extracting precious metals to excavating minerals and fossil fuels, mining has shaped societies and economies around the world. However, this vital industry has not come without its costs. The impact of mining on the environment and society is a complex and multifaceted issue that demands careful examination.

The mining industry of Brindletown and the South Mountain region was no exception. There were severe consequences for both the environment and the community. The goal of this research is to evaluate the environmental and societal impacts of the 1828 Gold Rush of.

### **Materials and Methods**

I visited the archives at the History Museum of Burke County, the Burke County public library, and the South Mountain State Park. I interviewed park rangers, librarians, and locals native to Burke County. I explored the South Mountain State Park, the South Mountain Game Lands, the forest at Western Piedmont Community College, the cemeteries at the Silver Creek Church, and the cemeteries at the Broughton Hospital.

### **Results**

I categorized my data into 3 categories: pre-gold life, gold mining methods, and post gold-life to highlight what changed as a result of the new industry.



### Pre-Gold Life:

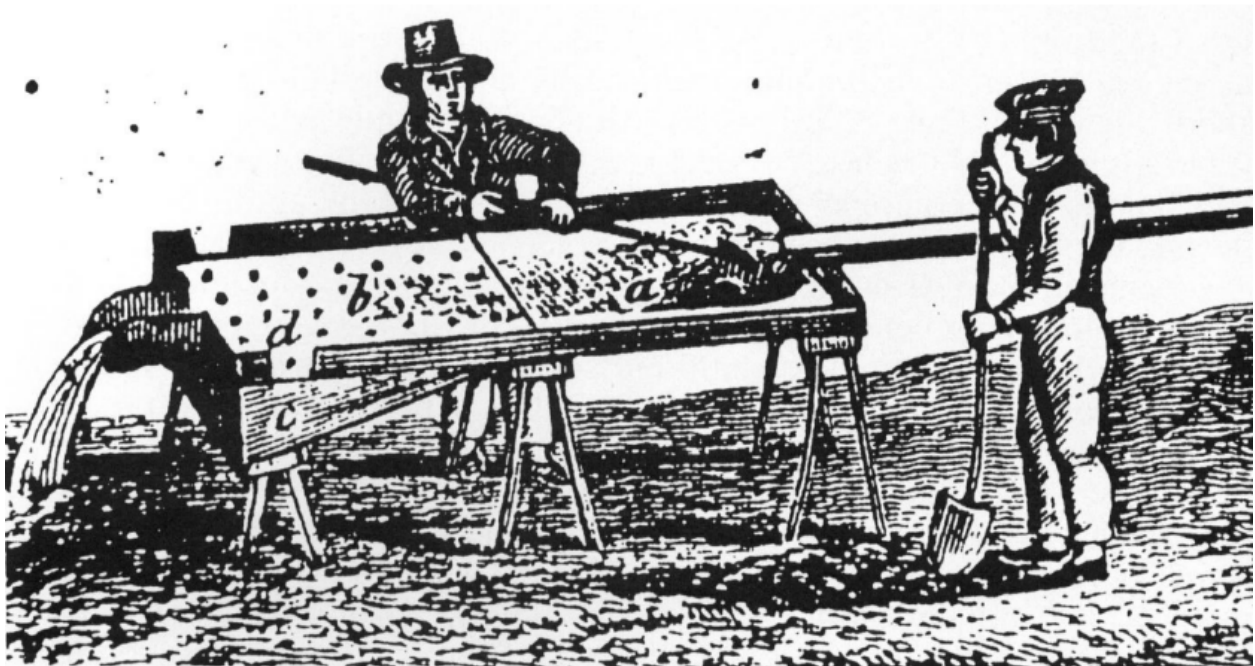
The people of Brindletown were self-sufficient. They used almost no external resources, imports, and didn't waste any resources. They grinded hard corn, toasted pigs feet until the hooves came off, and ate raccoon, turtle, and squirrel regularly [Depriest, 1987]. I interviewed William Watts, whose ancestors were some of Brindletown's original residents. When asked about how society functioned at this time, he explained that "People didn't really have jobs".

### Gold Mining Methods:

From the primary sources at the History Museum of Burke County, the Burke County public library, and the South Mountain State Park, I was able to determine that sluice boxes and mercury amalgamation were the 2 most common mining methods. [Wall text, 2023]. At the time, most pollution went unrecorded, and there were virtually zero legal restraints on mining practices [Knapp, Glass, 1999].

The South Mountains State Park reports that as many as 5,000 slaves were forced to work in the mines [NC, 2007]. As a reference point, the total population of Burke County in 1820, before the gold rush, was only around 10,000. [Burke County, 1820]

Figure 1: Sluice Box [Phillips, 1833]



### Post-Gold Life:

Brindletown residents who could once get everything they need in their own town could now get little beyond corn, vegetables, and beef. Instead, pork was imported from Kentucky,

bacon and flour from Tennessee, iron casting, mining tools, and clothing for slaves from Philadelphia or other manufacturing centers in the north [Phifer, 1963].

When the owner of a riverside mill, Mr Chase, threatened to sue JC Mills because his mining operation would harm the land, Captain Mills dismissed these concerns as a petty lawsuit. “We hope the owners will see the matter in the right light and do the clean, fair thing to do” wrote the captain [A Great Gold Venture, 1888].

Instead of setting regulations to mitigate environmental harm, the county government was likely more concerned with building their \$500,000 stone courthouse [Phifer, 1963]

Not long after the transformation of Brindletown, the same wealthy slave owners who radically altered the town left as quickly as they came. The promise of higher, more stable profits in cotton cultivation and railroad building were too alluring to resist [Poovey, 1967].

Table 1: Slave Population and Distribution [Burke County Census, 1850]

Year	# of Slaves
1820	1909
1830	2520
1840	3534
1850	2132

## Discussion

Essentially, the results of the data allows for a detailed timeline that shows the extent of the impact of the discovery of gold in Brindletown.

Before the discovery of gold, Brindletown, North Carolina, one of the first European-American towns in the South Mountains was a self-sufficient, waste-free society. In 1828, gold was found. Wealthy individuals poured into Burke County with hopes of amassing even more wealth. But, the exploitation of the natural land was only made possible by the exploitation of thousands of humans - slaves. In 1820, before the gold rush, the slave population in Burke County was 1909. The gold rush brought in as many as 5,000 slaves to work in the mines, over a 150% increase.

Sluice boxes and mercury amalgamation were the 2 most common mining methods in Brindletown. The mining operations of the gold rush resulted in severe environmental consequences. However, there were no studies on the environmental impact of mining during the 1820s, when this damage took place. So, we have to take our knowledge of what mining methods were used, and work backwards to understand the impact today.

Sluice boxes are long wooden channels with ridges designed to catch gold as water flows through it. A 2014 study focused on the effects of small-scale mining in 6 countries found that sluice boxes cause habitat destruction and water pollution. Sluice beds remove large amounts of

sand and gravel from streambeds, and then the used, murky water is dumped back into the streams, depositing pollutants and disrupting the livelihoods of native plants and animals who rely on the streams [Ashman, 2014].

Next, Mercury. Because mercury binds to gold, a popular mining technique used in the South Mountains was to bind mercury and gold in the water to make the gold easier to collect [Hines, 2002]. Miners in this era were unaware of the poisonous nature of mercury, and the risk they created by adding mercury to the water supply. Today we can observe the disastrous impact of mercury amalgamation mining in studies like one completed in the Philippines in 1999. Researchers visited Mount Diwata, a site with mercury amalgamation mining operations in the mountains and towns downstream - similar to the South Mountains. The research team found that 71% of the miners and 38% of the people living downstream were classified as mercury intoxicated [Drasch, 1999].

## **Conclusion**

With a rising population, mining techniques with an unknown extent of harm, a government not equipped, or willing, to intervene, and an upper class with tremendous power, Brindletown would not stay the same. Brindletown's self-sufficient farming economy couldn't withstand the rapid pressures of capitalism. The population had grown so much that the town became dependent on imports to meet their basic needs. This shift towards a more market-driven economy introduced the concept of commodification, creating a division between consumers and producers. The emphasis on exchange value and accumulation of wealth threatened Brindletown's traditional, communal structure and laid the foundation for a capitalist shift within Brindletown. The 1828 gold rush left a lasting impact on the local environment and society. Moreover, the way the gold rush developed shows just how intertwined the environment and society are.

## Works Cited

- “A Great Gold Venture by a Gentleman of Great Experience.” *The Morganton Star*, 30 March 1888, [newscomnc.newspapers.com](http://newscomnc.newspapers.com)
- Ashman, Irina. “How ‘Small’ is Small-Scale Gold Mining?” *International Pollution Issues* (2014) <https://intlpollution.commons.gc.cuny.edu/how-small-is-small-scale-gold-mining>
- “Burke County North Carolina: 1820 Census.” Slave Population and Distribution, Burke County, Drasch G, Böse-O'Reilly S, Beinhoff C, Roider G, Maydl S. The Mt. Diwata study on the Philippines 1999--assessing mercury intoxication of the population by small scale gold mining. *Sci Total Environ.* 2001 Feb 21;267(1-3):151-68. doi: 10.1016/s0048-9697(00)00806-8. PMID: 11286210.
- Depriest, Joe. “Farm Families Were Self-Sufficient.” *The Shelby Star*, 19 August 1987, p. 9
- Hines, Elizabeth, and Michael S. Smith. “GOLD IS WHERE YOU FIND IT: PLACER MINING IN NORTH CAROLINA, 1799–1849.” *Earth Sciences History*, vol. 21, no. 2, 2002, pp. 119–49. *JSTOR*, <http://www.jstor.org/stable/24143479>. Accessed 22 June 2023.
- Knapp and Glass, “Gold Mining in North Carolina.” North Carolina Office of Archives and History, 1999.
- North Carolina. 2007. South Mountains State Park. Raleigh, NC: Division of Parks and Recreation. <https://digital.ncdcr.gov/digital/collection/p16062coll9/id/217140>
- Phifer, Edward. “Champagne at Brindletown: The Story of the Burke County Gold Rush, 1829-1833.” *The North Carolina Historical Review*, Vol. 40, Issue 4, Oct 1963.
- Phillips, William,. "Essay on the Georgia Gold Mines." Hargrett Library. 1833, [https://dlg.galileo.usg.edu/do:guan\\_rbko\\_rbko-779](https://dlg.galileo.usg.edu/do:guan_rbko_rbko-779).
- Poovey, Ruth Royal. “The Burke County Gold Rush”. Burke County Cultural Historical Project, Title 3, 1967.
- Wall text, Burke Co. Gold Rush 1828-1833, History Museum of Burke County, Morganton, NC.

# **The Symbiotic Connection of Brain and Gut: Neuronal Dysfunction in the Brain due to Gut Inflammation By Catherine Xu**

## **Abstract**

The gut-brain microbiota axis is a communication pathway linking the enteric nervous system of the body. It has become an area of increased interest over the past few years because of the potential to improve overall health. This bidirectional network allows the brain to influence intestinal activities, but also allows the gut to influence mood, cognition, and mental health. While it may be more clear how the cognitive aspect influences the gut microbiome, more questions may arise on the topic of the gut microbiome having significant influence on the gut-brain axis, as any change to this environment has the potential of changing the condition and function of the brain. Recent research has also linked gastrointestinal inflammation with neurodegeneration, especially with diseases such as Alzheimer's and Parkinson's Disease through the vagus nerve. This review will explore the gut-brain microbiota axis and its association with neurodegenerative disorders.

## **Introduction**

The gut-brain microbiota axis is a communication pathway linking the enteric nervous system of the body, but also including the endocrine, humoral, metabolic, and immune routes of communication spanning through the body. In this well established bidirectional network, the gut microbiome exerts a major influence on human health and plays a crucial role in various physiological processes.

The enteric nervous system (ENS) is made up of 400-600 million neurons of up to 20 different types that line the walls of the gastrointestinal (GI) tract. The ENS receives signals from the central nervous system, but it is able to perform functions such as propulsing food, nutrient handling, bowel flow regulation, and immune system defense on its own. It has also been associated with the epithelial barrier, which plays an essential role in maintaining host homeostasis. It does this by regulating nutrient absorption and as preventing the invasion of pathogenic bacteria in the host.

The vagus nerve, the main nerves of the parasympathetic nervous system controlling specific body functions such as digestion and heart rate. Although it is possible for the gut microbiome to communicate through the endocrine and immune pathways, the vagus nerve pathway is the fastest and most direct way for the gut to communicate with the brain. However, this communication is often associated with diseases and disorders.

The gut microbiome refers to the complex and dynamic population of microorganisms, bacteria, viruses, fungi, and their genetic material in the GI tract. With around 3.3 million, over ten times more genes than the 23,000 in the human genome, they have a significant influence on the physical and mental state of the body. They play a crucial role in maintaining the immune and metabolic systems, while protecting the body against pathogens. When the gut bacterial composition is altered (dysbiosis), it is often because of inflammatory diseases and infections.

A human's gut microbiota is established during infancy, but shaped throughout a lifetime mainly through diet and lifestyle, resulting in a unique gut composition for each individual. The gut microbiome evolves in three phases: a developmental phase from 3-14 months old, a transitional phase from 15-30 months old, and a stable phase beginning from 31 months old. It is generally known that greater diversity in the gut microbiota is associated with better health and lower risk of disorders in the body, as the diversity is able to better protect an individual from unknown pathogens.

### **Inflammation in the Gut**

Inflammation is known as a localized physical condition in which parts of the body show signs of redness, swelling, and hot and painful reactions as a response to an injury or infection. It is triggered by cells when the body's immune system senses danger, and will intensify over time if the inflammation is not stopped.

The gut, like other organs, is equipped with defense mechanisms to protect itself from pathogenic microbes. Even though the GI tract's purpose is digestion and absorption, bacteria and viruses still have the opportunity to invade this area of the body. Intestinal inflammation is caused by dysbiosis and impairment of the intestinal epithelial cells, which may promote the development of various disorders within the body. The intestinal epithelium, a monolayer along the intestines made of specialized intestinal epithelial cells, is the first line of defense by forming physical and chemical barriers along the intestinal mucosa. The physical barriers include the mucus layer, a layer of fluid secreted by the goblet cells. Since the large intestine has much more intestinal bacteria than the small intestine, the number of goblet cells are much greater in the large intestine, which leads to a thicker mucus layer. Although the small intestine has a smaller physical barrier because of the lack of goblet cells compared to the large intestine, the small intestine utilizes chemical barriers such as antimicrobial peptides for protection instead.

### **Neurological Diseases due to Gut Inflammation–Parkinson's Disease**

Parkinson's Disease (PD) is a neurodegenerative disease that causes unintended and uncontrollable movements. Such could include, but is not limited to, shaking, stiffness, and difficulty with balance and coordination. A protein called  $\alpha$ -synuclein drives PD occurrence and development, and is hypothesized to start in the intestine. It will then spread into the central nervous system via the vagus nerve. The same expression of  $\alpha$ -synuclein has been found in inflammatory bowel disease (IBD), characterized by inflammation of the GI tract, helping scientists connect intestinal inflammation and dysbiosis to the development and occurrence of PD. The protein spreads from gut to brain through cell-to-cell transfer. Even in mice, when an injection of  $\alpha$ -synuclein fibrils was put in the gut of the mice, it led to spreads of fibrils and neurodegeneration of brain regions involved in PD. There is also evidence that the aggregation of  $\alpha$ -synuclein could be due to imbalances in the gut microbiota, which causes increased levels

of stress in the gut. With this possibility, it could lead to the misfolding and formation of  $\alpha$ -synuclein.

### **Alzheimer's Disease**

Alzheimer's Disease (AD), involves parts of the brain that control thought, memory, and language. AD is a progressive neuronal dysfunction disease beginning with memory loss and leading to not being able to have a conversation and respond to the environment. It affects areas of the brain such as the cerebral cortex and hippocampus, and has been associated with the accumulation of the amyloid- $\beta$  peptide in the brain tissue and its blood vessels. Microglia are the immune cells of the brain, and play a crucial role in the development and progression of inflammation in the brain and the development of AD. The primary initiator to activate microglia in AD is the accumulation of the amyloid- $\beta$  peptide. The activated microglia then activates a mediated inflammatory response, resulting in the release of proinflammatory factors. After this, the microglia will lose their phagocytic effect, which allows for the amyloid- $\beta$  peptide to accumulate and take over.

Very similar to  $\alpha$ -synuclein in PD, amyloid- $\beta$  peptide has been believed to be released from the gut microbiome and trigger the misfolding for neuronal proteins, eventually activating neuroinflammation. When looking at the gut microbiome of individuals affected by AD, it was seen that the microbial diversity in the individual has decreased compared to those without the disease. As individuals age, dysbiosis of the gut occurs. Dysbiosis of the gut microbiome interferes with gastrointestinal permeability and the blood brain barrier. This has been associated with neurodegeneration.

### **Current and Future Treatments**

Currently, the stimulation of the vagus nerve has been used in order to treat many diseases, including PD and AD. Vagus nerve stimulation has the potential to target multiple AD and PD mechanisms as well as alter disease progression by supporting neuronal plasticity and providing anti-inflammatory signaling. Left vagus nerve stimulation is mainly for minimizing cardiac effects, while stimulation of the right vagus nerve is used for heart failure. Vagus nerve stimulation was recently approved by the FDA for the treatment of drug resistant epilepsy and depression, with more than 125,000 total patients worldwide already treated using this method. Vagus nerve stimulation has also been of interest in the treatment of long term or chronic inflammatory diseases. The anti-inflammatory properties of the vagus nerve gives more possibilities of minimizing symptoms for more diseases. With continuing research, treatments targeting the vagus nerve may be applied to neurological conditions including PD and AD.

In Parkinson's Disease, there have been treatments in attempt to increase, replace, or prevent the breakdown of dopamine to help stop the pathogenesis of PD and to help with the symptoms. While they do sound extremely promising, these treatments (usually in forms of surgery or medication) have resulted in side effects and unwelcoming results. Due to these results, scientists have looked into the gut microbiome as a way of treating PD, due to their link.

When an individual has PD, there are specific differences in the bacteria of their gut microbiome to a healthy individual. Some methods include attempting to reduce or increase specific bacterial species through antibiotics and probiotics, while other methods use prebiotics and fecal microbiota transplantation in order to change the composition of the gut microbiome. Through these treatments, it may be possible to improve or prevent PD.

## **Conclusion**

Emerging research has highlighted an interesting link between the gut microbiome and the brain, especially when it comes to inflammation and neurodegenerative diseases such as AD and PD. The interplay between gut bacteria and brain health underscores the start of potential research and breakthroughs at preventing cognitive decline. The influence of psychostimulants reflects the intricate bidirectional relationship between the gut microbiome and mental wellbeing. As we delve deeper into understanding these connections, we will pave new roads for therapeutic strategies and interventions that target the gut-brain microbiota axis, and help improve the lives of those who suffer with AD, PD, and other neurodegenerative disorders.



## Works Cited

- Appleton, Jeremy. "The Gut-Brain Axis: Influence of Microbiota on Mood and Mental Health." *Integrative Medicine (Encinitas, Calif.)*, U.S. National Library of Medicine, Aug. 2018, [www.ncbi.nlm.nih.gov/pmc/articles/PMC6469458/#:~:text=The%20gut%2Dbrain%20axis%20is,routes%20of%20communication%20as%20well](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC6469458/#:~:text=The%20gut%2Dbrain%20axis%20is,routes%20of%20communication%20as%20well).
- Author links open overlay panelKrishaa L. a, et al. "Gut-Brain Axis through the Lens of Gut Microbiota and Their Relationships with Alzheimer's Disease Pathology: Review and Recommendations." *Mechanisms of Ageing and Development*, Elsevier, 1 Feb. 2023, [www.sciencedirect.com/science/article/pii/S0047637423000131](http://www.sciencedirect.com/science/article/pii/S0047637423000131).
- Carabotti, Marilia, et al. "The Gut-Brain Axis: Interactions between Enteric Microbiota, Central and Enteric Nervous Systems." *Annals of Gastroenterology*, U.S. National Library of Medicine, 2015, [www.ncbi.nlm.nih.gov/pmc/articles/PMC4367209/#:~:text=The%20gut%2Dbrain%20axis%20\(GBA,microbiota%20in%20influencing%20these%20interactions](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4367209/#:~:text=The%20gut%2Dbrain%20axis%20(GBA,microbiota%20in%20influencing%20these%20interactions).
- Carabotti, M., Scirocco, A., Antonietta Maselli, M., & Severi, C. (2015). The gut-brain axis: interactions between enteric microbiota, central and enteric nervous systems (Vol. 28).
- Chen, X., D'Souza, R., & Hong, S. T. (2013). The role of gut microbiota in the gut-brain axis: Current challenges and perspectives. In *Protein and Cell* (Vol. 4, Issue 6, pp. 403–414). Higher Education Press.
- Fleming, M. A., Ehsan, L., Moore, S. R., & Levin, D. E. (2020). The Enteric Nervous System and Its Emerging Role as a Therapeutic Target. In *Gastroenterology Research and Practice* (Vol. 2020). Hindawi Limited.
- Fülling, C., Dinan, T. G., & Cryan, J. F. (2019). Gut Microbe to Brain Signaling: What Happens in Vagus.... In *Neuron* (Vol. 101, Issue 6, pp. 998–1002). Cell Press.
- Thursby, E., & Juge, N. (2017). Introduction to the human gut microbiota. In *Biochemical Journal* (Vol. 474, Issue 11, pp. 1823–1836). Portland Press Ltd.
- Jandhyala, S. M., Talukdar, R., Subramanyam, C., Vuyyuru, H., Sasikala, M., & Reddy, D. N. (2015). Role of the normal gut microbiota. *World Journal of Gastroenterology*, 21(29), 8836–8847.
- Bander, Z. al, Nitert, M. D., Mousa, A., & Naderpoor, N. (2020). The gut microbiota and inflammation: An overview. In *International Journal of Environmental Research and Public Health* (Vol. 17, Issue 20, pp. 1–22). MDPI AG.
- Carding, S., Verbeke, K., Vipond, D. T., Corfe, B. M., & Owen, L. J. (2015). Dysbiosis of the gut microbiota in disease. *Microbial Ecology in Health & Disease*, 26(0).
- Wilkins, L. J., Monga, M., & Miller, A. W. (2019). Defining Dysbiosis for a Cluster of Chronic Diseases. *Scientific Reports*, 9(1).
- Rinninella, E., Raoul, P., Cintoni, M., Franceschi, F., Miggiano, G. A. D., Gasbarrini, A., & Mele, M. C. (2019). What is the healthy gut microbiota composition? A changing ecosystem across age, environment, diet, and diseases. *Microorganisms*, 7(1).

- Derrien, M., Alvarez, A. S., & de Vos, W. M. (2019). The Gut Microbiota in the First Decade of Life. In *Trends in Microbiology* (Vol. 27, Issue 12, pp. 997–1010). Elsevier Ltd.
- Hakansson, A., & Molin, G. (2011). Gut microbiota and inflammation. In *Nutrients* (Vol. 3, Issue 6, pp. 637–687). MDPI AG.
- Pahwa, R., Goyal, A., & Jialal, I. (2022). *Chronic Inflammation*. StatPearls Publishing.
- Haller, D. (2018). The gut microbiome in health and disease. In *The Gut Microbiome in Health and Disease*. Springer International Publishing.
- Coskun, M. (2014). Intestinal epithelium in inflammatory bowel disease. *Frontiers in Medicine*, 1(AUG).
- Okumura, R., & Takeda, K. (2017). Roles of intestinal epithelial cells in the maintenance of gut homeostasis. In *Experimental and Molecular Medicine* (Vol. 49, Issue 5). Nature Publishing Group.
- Rooks, M. G., & Garrett, W. S. (2016). Gut microbiota, metabolites and host immunity. In *Nature Reviews Immunology* (Vol. 16, Issue 6, pp. 341–352). Nature Publishing Group.
- Kawasaki, T., & Kawai, T. (2014). Toll-like receptor signaling pathways. In *Frontiers in Immunology* (Vol. 5, Issue SEP). Frontiers Media S.A.
- Holmes, E., Li, J. v., Marchesi, J. R., & Nicholson, J. K. (2012). Gut microbiota composition and activity in relation to host metabolic phenotype and disease risk. In *Cell Metabolism* (Vol. 16, Issue 5, pp. 559–564). Cell Press.
- Hu, W., & Spink, H. P. (2022). The Role of TLR2 in Infectious Diseases Caused by Mycobacteria: From Cell Biology to Therapeutic Target. In *Biology* (Vol. 11, Issue 2). MDPI.

# The Development of Ancient Chinese Cosmology and Its Interactions with Politics By Ke Li

## Abstract

This article traces the development of ancient Chinese cosmology from the Shang Dynasty to the Han Dynasty and analyzes the role of political factors in shaping it. During the Shang Dynasty, ancient Chinese cosmology revolved around the concepts of “Ti” and “ancestors,” where only the king could influence Ti through his ancestors and predict the Ti’s actions through divination. However, during the Zhou Dynasty, the Zhou kings elevated the concept of “Tian,” a natural deity, above Ti, effectively overthrowing Shang Dynasty rule. During the Warring States period, various states began to develop more complex mythological systems, continuing the early Zhou Dynasty concept of the “Five Elements” to weaken the authority of the Zhou kings. Finally, during the Han Dynasty, people believed that various celestial phenomena reflected the “emotions” of the universe. The concept of “Emperor” as a nexus between the human world and the cosmos emerged. Consequently, the study of astronomy and natural phenomena was no longer aimed at understanding nature itself but rather at achieving political goals. In conclusion, from the Shang Dynasty to the Han Dynasty, ancient Chinese cosmology was primarily constructed not to explore the natural rules of the universe but to serve political science.

## 1. Introduction:

Joseph Needham posed the famous “Needham Question” in his work *Science and Civilization in China* [1]: Why did China produce many technological inventions (such as the Four Great Inventions) but did not develop comprehensive modern sciences like physics, as established by Newton? Some argue that ancient China did “have science” but in a different form compared to the West, which Needham regarded as “unsuccessful.” For instance, during the Shang-Zhou period, Chinese mathematics and astronomy were highly developed, with detailed records of celestial phenomena, even the concept of irrational numbers [2]. But regardless of whether ancient China developed a systematic science, the fundamental question in addressing Needham's query is: Why did Chinese ancient science develop so differently from the West? This article proposes a new perspective to understand the difference between ancient Chinese and Western sciences: by analyzing the development of ancient Chinese cosmology.

## 2. Why the Shang Dynasty Chinese Were Obsessed with Recording “Astronomy”

In the Shang Dynasty, people believed that “Ti” resided in the heavens, and the ancestors of the king, nobility, and common people ascended to the heavens. The heavens were even thought to be infinite. Thus, heaven held extreme significance for the Shang people. Among these, the ancestors of the king were closest to Ti, and even after the king's death, they continued to “serve by the Ti's side.” Other nobles and meritorious figures followed, but they are further away from Ti than the kings. However, in Shang Dynasty, people believed that a person's earthly

life and promotion were not influenced by their ancestors. Furthermore, people's prayers could not directly affect Ti. They could only pray to their ancestors that their ancestors would influence Ti or predict Ti's actions through divination, such as rain and the banishment of “evil spirits.” Since the ancestors of the king were closest to Ti, they were the most capable of explaining natural phenomena and influencing Ti. Therefore, astronomical observations were of paramount importance to the people of that time, even to the extent that the arrangement of accompanying items in their graves, such as shells, might be related to celestial phenomena (Fig 1, Tomb 45 at Xishuipo).

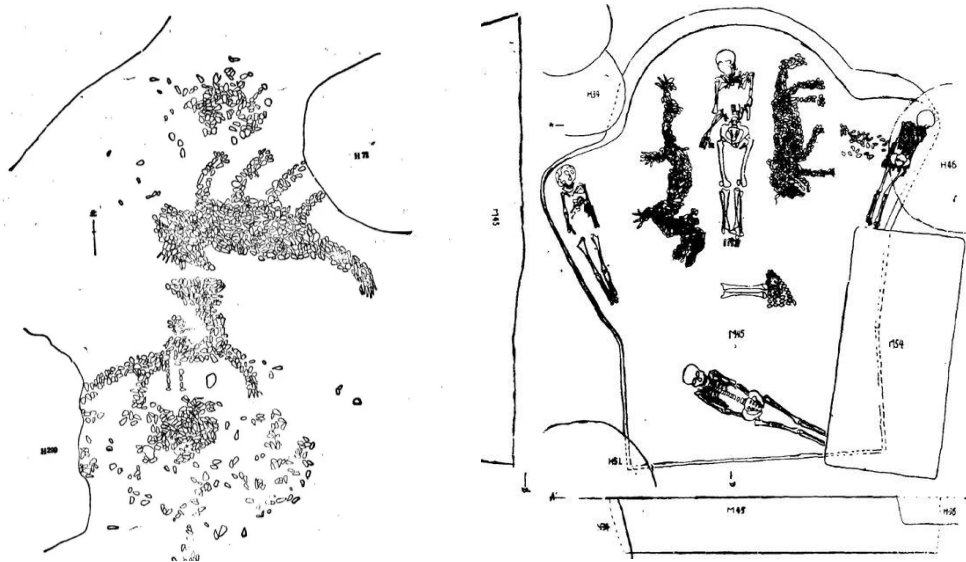


Fig 1, Tomb 45 at Xishuipo

Astronomical records during the Shang Dynasty were precise and comprehensive, including observations of the North Star, seasonal divisions based on sunrise and sunset, and more. To understand the interaction between heaven and earth, the Shang people developed advanced mathematics, as demonstrated in the *Zhou Bi Suan Jing*, which provided a detailed proof of the Pythagorean theorem to quantitatively calculate the relationship between shadows and the sun.

The Shang Dynasty people also had a concept of centrality and the four cardinal directions. They believed that the heavens were like a dome covering the earth, with a connection between heaven and earth, and four corners in the far distance from the center of the heavens, known as the four “directions” ( or four “poles”). Thus, they thought that the four directions were actually closer to heaven. However, their focus was primarily on the center because they believed that “Ti” resided at the center of heaven. Some scholars believe that the ancient Chinese thought of the earth as a flat plane because they considered tall or deep things to be magical. Yet, this is not entirely accurate. For the ancients of Shang Dynasty, the greater influence was determined by the proximity of one’s ancestors to “Ti,” not by depth or height. For

example, people did not find anything mysterious about “Mount Bu Zhong” even though it was considered a celestial pillar connecting the earth and the heaven. This was because people were mainly concerned with “Ti” which resides at the center of heaven. It is evident that the ancient Shang people did not have an intense worship of the underground world or the tall mountains. Moreover, the term “方” itself denotes the concept of “space,” suggesting that the Shang people likely did not envision the earth as a flat plane but rather as a three-dimensional “space.” Furthermore, the way the Shang Dynasty people handled conflicts with neighboring states was also related to their interpretation of the concepts of centrality and the four “directions”. During the Shang Dynasty, the people believed that wherever the king was, that was the center of the world. Therefore, they regarded their own location as the center and other neighboring states as the four directions. When conflicts arose with neighboring states, who were militarily stronger, the king would proclaim that the war was caused by evil spirits. They often used phrases like “evil spirits attacked from the east.” This information was recorded as part of their warfare. As a result, they began praying to gods from the four directions. It is clear that from the Shang Dynasty onward, ancient Chinese cosmology and the concept of heaven and earth were already influenced by politics.

### **3. Zhou Dynasty Cosmology and the Concept of the Five Elements:**

During the time of King Wen of Zhou, Ji Chang, the absolute authority of “Ti” was dismantled. “Tian”(Heaven) is a deity that has a deeper and more direct impact on the human realm than “Ti”. King Wen proclaimed that “Ti” might not necessarily bless the human world, and it was necessary to seek favor with both the king and his ancestors. “Tian” symbolized the voices and interests of the people, and “Heaven listens as our people listen; heaven watches as our people watch.” [3] It represented a “natural deity” rather than an “ancestral deity.” The deities people worshiped shifted from ancestral deities to natural deities. Simultaneously, King Wen compromised with the “wu” (shamans), and rituals and divination were no longer mandatory bloodline traditions but transformed into scholarly and academic pursuits. They became skills attainable through learning and education rather than proximity to Ti. Nevertheless, astronomy and cosmology remained crucial because everyone needed to cultivate themselves to receive blessings from “Tian.” Knowledgeable individuals, such as scholars and intellectuals, also needed to interpret natural phenomena to demonstrate their worth. Consequently, the concept of the “Five Elements” gradually emerged, representing the virtues of “benevolence, righteousness, propriety, wisdom, and trustworthiness.” Ordinary individuals could communicate with Heaven and Earth through the study of classics, as exemplified by Confucius. People no longer required kings to mediate between Heaven, Earth, and humans, significantly weakening the king's ability to harness celestial power. Simultaneously, the political and cultural center of the Zhou Dynasty was established near Luoyang, with the concept of the “center” gaining a clear and crucial geographic significance. In the later years of the Zhou Dynasty, what various feudal lords competed for was precisely this “central” position, and losing the “center” meant losing the “mandate of Heaven.”

During the Warring States period, the concept of the “Five Elements” underwent further transformation. Efforts were made to further weaken the concept of the “center,” leading to the development of China's mythological system. An educated class gradually emerged, and the complexity of the pantheon increased, resulting in the collapse of the previous power structure. The central authority of the Zhou monarchs was no longer absolute. In mythology, figures like Nüwa and Fuxi created four directional deities from the chaos, and their movements formed the sun, moon, stars, and the four seasons within the chaos. This gave new meaning to space. There was no longer a need for a central deity, as deities from the east, west, south, and north were powerful enough to assist the nation. Following this, the “Five Elements” were considered as five “attributes” related to colors, solar terms, etc., ultimately serving political purposes. For example, the Bamboo Slips from Tomb No. 45 of Suihoushan mentioned that gold conquers wood, wood conquers gold; the west is gold, the center is wood. Chinese philosophy was constructed on the idea of an immensely “large” universe, perhaps even infinite, as ancient people believed it was unnecessary to ask “how big” it was. They dedicated themselves to seeking deities that most directly influenced people's lives and political rule, focusing on the governance of the world.

#### **4. Han Dynasty Cosmology, the Five Elements, Calamities, and Auspicious Signs:**

About two thousand years ago, the concept of the “Five Elements” became linked once again with virtue and experienced new development in China. During that time, China began to embrace the teachings of Huang-Lao. Ancient Chinese believed that the principles governing the universe and the operation of the state were the same, relying on the “Five Elements.” Before Confucius, the term “junzi” referred to representatives of the nobility. Later, Confucius believed that a junzi should cultivate oneself to bring peace to others and the common people, achieve merit, and expand outward. However, the Huang-Lao teachings of the Han Dynasty advocated inward development, a return to nature, the cultivation of virtue, and the attainment of the mental and physical status of the Yellow Emperor. People believed that the path to becoming like the Yellow Emperor lay not only in achieving merit. Figures like Shang Yang achieved merit and governed the state, but their endings were still tragic. However, the Yellow Emperor interacted with the Five Elements, delivering the world to the people and ascending to heaven. Achieving merit might influence others but not necessarily improve oneself. In the depths of the universe, there exist forces imperceptible to humans on Earth: people might not attain the status of the Yellow Emperor on Earth, but they could spiritually reach his state. People believed that each individual contained a universe within themselves, with their internal organs corresponding to the “Five Elements” of the cosmos, and the body's acupoints corresponding to celestial bodies. If there were problems in the cosmos, disasters would befall the human realm.

After declaring himself emperor, Liu Bang of the Han Dynasty implemented a system of commanderies and kingdoms, followed the principles of Huang-Lao to govern passively, and allowed the people to rest. The country attained the “Fire Virtue” of the Five Elements. The emperor became the supreme figure on Earth, the one most capable of interacting with the

universe, influencing the operation of the cosmos, and reflecting its changes. The emperor became a “legacy” that had to exist regardless of the state of the imperial family or society as a whole. The emperor became a symbol of cosmic order and bore the responsibility for heavenly disasters on earth for the people and the nobility. From then on, people no longer contested the “mandate of Heaven” or the “center” but rather contended for the position of Emperor. Dong Zhongshu altered Confucianism and Huang-Lao thought, emphasizing that virtue had a beginning and an end, and the Five Elements had cycles. The operation of the human body paralleled that of the universe. Therefore, celestial phenomena, such as shooting stars and comets, were expressions of the universe's “emotions.” The human realm was closely linked to the heavens, and the suffering and disasters in the human realm could lead to divine punishments. However, if the emperor behaved improperly and lost his virtue, he would lose the protection of the cosmos. The best emperor was one who united the entire realm and fostered harmony. By cultivating virtue, the emperor could expand his domain and attain the highest authority. The emperor always hoped for auspicious signs, which would enable him to wage wars, initiate reforms (reduce the power and land of the nobility) and expand his territory. On the other hand, scholars (who were often well-versed in both literary and martial arts) hoped for disasters and plagues, as these could lead to their promotion and merit.

From that point on, imperial authority became a “hub,” not just associated with a particular individual but rather a legacy generated by the heavens, the earth, and the universe. Celestial phenomena (earthquakes, shooting stars, etc.) became the primary subjects of discussion. As Confucius said, “The knowledge of the superior and the ignorance of the inferior are not the same.” Interpretations of celestial phenomena were related to an individual's virtue and status. Emperors balanced the interests of the nobility through auspicious and disastrous celestial phenomena, while Confucianism sought ways to advance through these phenomena. Celestial phenomena became a tool for emperors, Confucianism and the nobility to compete for power and counterbalance each other.

As a result, people were no longer concerned about what the stars in the sky looked like or how they operated under specific rules like Isaac Newton did. No one cared about the science we define today, which is probably why the Greeks had already estimated the Earth's radius while China remained unaware that the Earth was spherical. People were primarily interested in how celestial phenomena could be used for governance and to achieve their political goals. This is the interaction between politics and cosmology in ancient China.

## **5. Conclusion:**

Ancient Chinese philosophy and cosmology, since the Shang Dynasty, did not focus on precisely defining the “universe” or “ancestors” themselves or rigorously describing them. Instead, they aimed to construct a vast cosmological framework. The larger the framework, the more room for reinterpretation, making it easier to reshape. The core goal was to contribute to political philosophy and marginalize the once-almighty “deities.” During the Shang Dynasty, the concept of “center” and “emperor” was used to solidify rule. During the Zhou Dynasty, King

Wen used the concept of “Tian”, a natural deity, to replace the ancestral deity “Ti” and overthrow the Shang Dynasty. In the later years of the Zhou Dynasty, various feudal states composed more complex mythological systems, linking the Five Elements with five attributes to weaken the authority of the Zhou monarchs. In the Han Dynasty, the emperor became a revered figure who served as the intermediary between Earth and the cosmos, and celestial phenomena were considered expressions of the universe's “emotions.” People primarily studied astronomy for political purposes. The interaction between politics and cosmology in ancient China remained a “subtle” one, perhaps one of the reasons why ancient China did not give birth to modern natural science.



## Works Cited

- Needham, Joseph, 1969. *Science and Civilisation in China, Vol. 2, History of Scientific Thought* (Cambridge: Cambridge University Press).
- Feng, Shi, 2006. *Zhongguo de gudai tianwen yu renwen* (No Title) Gu, Qian. *Shangshu*. BEIJING BOOK CO. INC., 2016. Confucius. *Lunyu*. BEIJING BOOK CO. INC., 2015.
- Allan, Sarah, 1981. *The Heir and the Sage: Dynastic Legend in Early China* (San Francisco: Chinese Materials Research Center).
1991. *The Shape of the Turtle: Myth, Art and Cosmos in Early China* (Albany: State University of New York).
2009. "On the Identity of Shang Di and the Origin of the Concept of a Celestial Mandate (*Tian Ming*)," *Early China* 31, 1–46.
2010. "T'ien and Shang Ti in Pre-Han China," *Acta Asiatica* 98, 1–18.
2011. "Literacy and the Emergence of Writing," *Writing & Literacy in Early China: Studies from the Columbia Early China Seminar*, 51–84.
- Brooks, E. Bruce and Brooks, A. Taeko, 1998. *The Original Analects: Sayings of Confucius and His Successors* (New York: Columbia University).
- Di Cosmo, Nicola, 2002. *Ancient China and Its Enemies: The Rise of Nomadic Power in East Asian History* (Cambridge: Cambridge University Press).
- Fingarette, Herbert, 1998. *Confucius: The Secular As Sacred* (Prospect Heights, IL: Waveland).
- Goldin, Paul R. 2008. "The Myth that China Has no Creation Myth," *Monumenta Serica* 56, 1–22.
1982. "Akatsuka Kiyoshi and the Culture of Early China: A Study in Historical Method," *Harvard Journal of Asiatic Studies* 42.1, 267–320.
1985. *Sources of Shang History: The Oracle-Bone Inscriptions of Bronze Age China* (Berkeley: University of California).
1999. "The Environment of Ancient China," in Michael Loewe and Edward L. Shaughnessy (eds.), *The Cambridge History of Ancient China, from the Origins of Civilization to 221 B.C.* (Cambridge: Cambridge University Press), 30–6.
- Lewis, Mark Edward, 1990. *Sanctioned Violence in Early China* (Albany: State University of New York).
1981. "Time and Knowledge in China and the West," in J.T. Fraser (ed.), *The Voices of Time: A Cooperative Survey of Man's Views of Time as Expressed by the Sciences and by the Humanities* (Amherst: University of Massachusetts), 233–6.

## **Exploring the Longitudinal Trends in Sex, Age, Nationality and Performance in Sport: A Comprehensive Statistical Analysis By Mariam Husain**

### **Abstract**

This study will analyze the longitudinal sport performance in specific track and field events, including the 100 m, 1500 m, the marathon, and others. Data from worldathletics.org was used, including individual athlete statistics, team performance metrics, and relevant technological advancements. Statistical methods carried out in Google Sheets and Excel will validate or refute hypotheses about performance evolution. Graphs have been made displaying the data and a Chi Squared test was run to establish how well the observed distribution of data fits with the distribution that is expected if the variables are independent. Insights on factors influencing performance will be valuable for athletes, coaches, and sports scientists, with analyses based on sex, age, and nationality. This work emphasizes the significance of continuous analysis and adaptation in optimizing athletic performance through technology and training in track and field events.

*Keywords:* longitudinal, performance, Chi Squared test

### **Introduction**

This project explores the sex-based performance differences between men and women based on nationality and age for the 100 m sprint, 1500 m race and 42 km marathon. Sex-based performance differences in athletes are caused by a combination of biological, physiological, and sociocultural factors. As current research in this area shows, men and women often display differences in speed, endurance, and other physical attributes, which, in turn, impact sports performance. Men generally tend to have an advantage in power-based sports due to greater muscle mass and bone density, along with higher levels of testosterone. On the other hand, women might excel in endurance events due to their higher percentage of body fat, which provides a more sustained energy source. However, it's important to note that these differences are averages and there is considerable individual variation. Sociocultural factors, training, and opportunities also play a crucial role in an athlete's performance.

### **Literature Review Paper : "Running Performance Differences between Men and Women"**

This paper discusses the trends in men's and women's running performance, and whether predictions that records for both genders will eventually intersect are true. However, this prediction has been found to have errors, partly due to a linear mathematical treatment and limited performance data. The authors of this paper suggest that the initial appearance of convergence between men's and women's running times was skewed by past historical biases. Today, women's running times have plateaued, similar to what has been observed in men's marathon performances, and similar trends are seen in other races from 100 to 10,000 meters. The remaining performance gaps between men and women appear to be primarily biological,

with men having greater aerobic capacity and muscular strength. Thus, it is unlikely that these performance differences will naturally narrow.

### Methodology

Data was acquired from <https://worldathletics.org/><sup>2</sup>. It was preprocessed, consolidated, and cleaned using Microsoft Excel. Analysis, visualizations, and statistical testing were also performed via Microsoft Excel. The race times provided in the dataset were analyzed through two different lenses: world record (WR) times and minimum times per year. The data was considered from these two different perspectives because it was found that some WR times remained constant for a significant period of time, therefore making it hard to measure athletic performance over the years.

The Chi squared test measures how well the observed distribution of data fits with the distribution that is expected if the variables are independent. By convention, the "cutoff" point for a p-value is 0.05; anything below that can be considered a very low probability, while anything above it is considered a reasonable probability.

### Results

The paper analyzes the correlation between the nationality of athletes and their performance in the 100 m, 1500 m, and 42 km races; then it analyzes the correlation between the age of athletes and their performance in the same races. All the comparisons are drawn between men and women.

### Nationality

100m	W	Nationality-Time	p<.001	Dependent
100m	M	Nationality-Time	p<.001	Dependent
1500m	W	Nationality-Time	p<.001	Dependent
1500m	M	Nationality-Time	p<.001	Dependent
42km	W	Nationality-Time	p<.001	Dependent
42km	M	Nationality-Time	p<.001	Dependent

Table 1  
*100m*

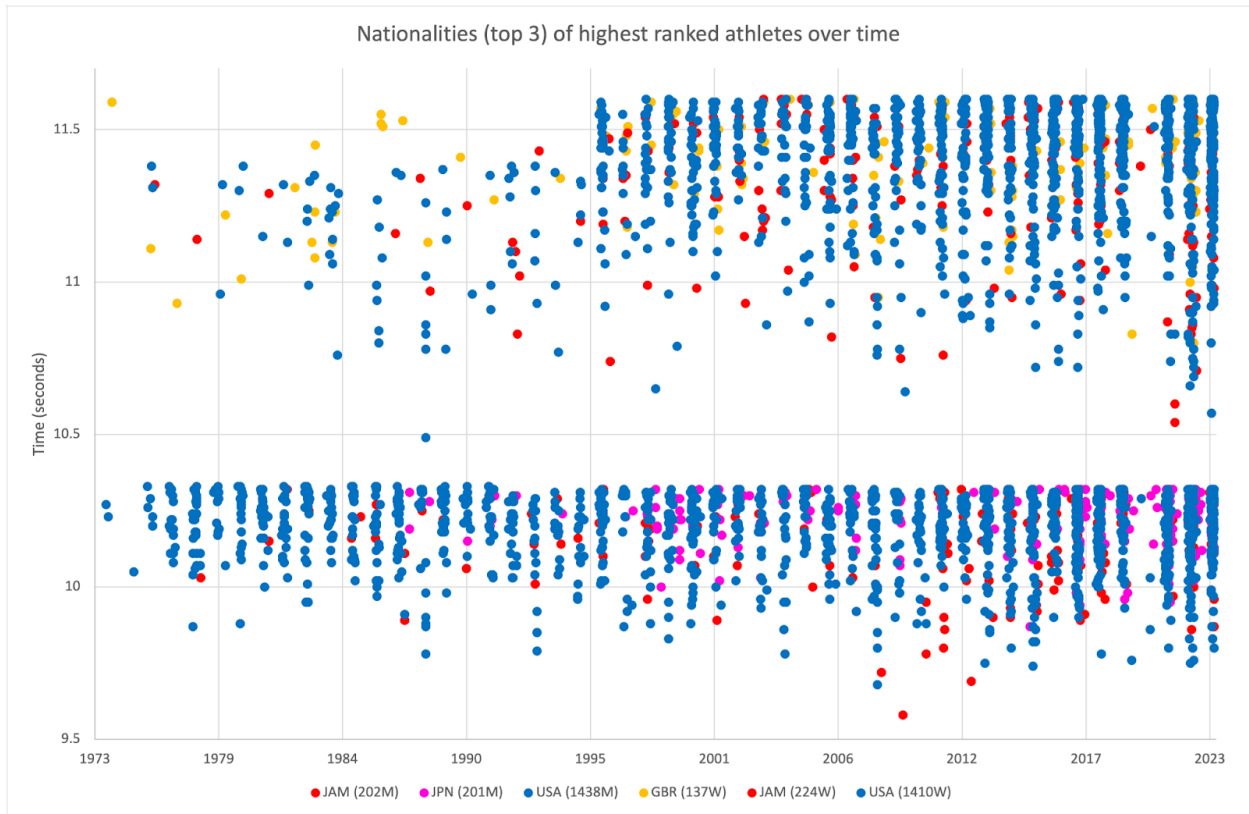


Fig 1: Top 3 Nationalities of highest ranked athletes over time (100 m)

The time taken for athletes to run the 100m is dependent on their nationality for men as well as women. We can see that certain nationalities are predisposed to characteristics that allow them to excel at running the 100m sprint. This event is dominated by Jamaican, Japanese, and American men, and Jamaican, American, and British women.

There is also a significantly larger number of women post 1995 who ran the 100 m under 11.5 seconds. This could be due to advances in training methods, or the increased inclusion of women in athletics.

## 1500m

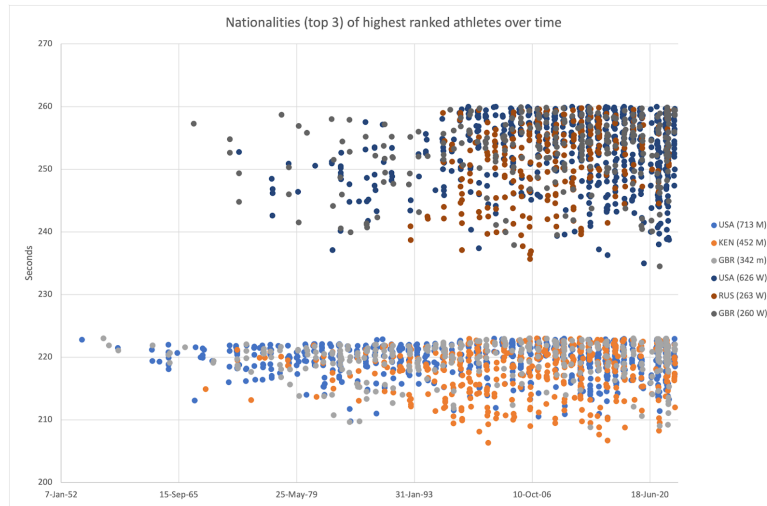


Fig 2: Top 3 Nationalities of highest ranked athletes over time (1500 m)

The time taken for athletes to run the 1500 m is dependent on their nationality for men as well as women. We can see that certain nationalities are predisposed to characteristics that allow them to achieve lower 1500 m timings. This event is dominated by American, Kenyan, and British men, and American, Russian, and British women.

There is also a significantly larger number of men and women post-1993 ran the 1500 m under 230 and 260 seconds, respectively. This could be due to advances in training methods, or the increased popularity and inclusion of this race.

## 42km

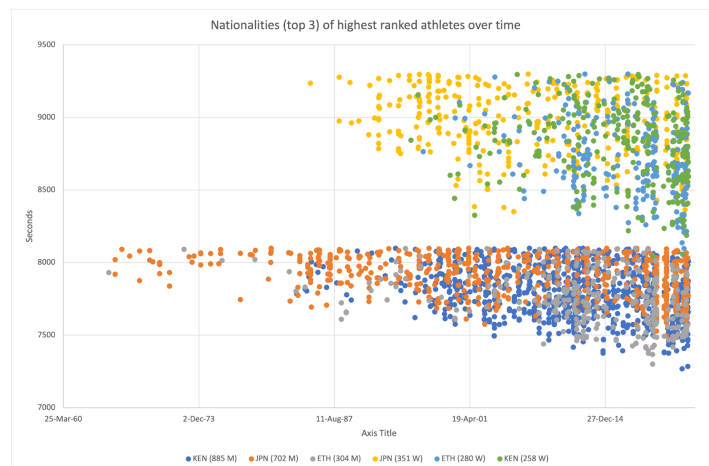


Fig 3: Top 3 Nationalities of highest ranked athletes over time (42 km)

The time taken for athletes to run the marathon (42 km) is dependent on their nationality for men as well as women. We can see that certain nationalities are predisposed to characteristics that enable them to run the marathon extremely fast. This event is dominated by Kenyan, Japanese, and Ethiopian men, and Japanese, Ethiopian, and Kenyan women.

Women began to run elite times not far before 1987, showing that it was probably uncommon, and in some cases, not permitted for women to participate in the marathon in earlier times.

**Age**

100m	M	Age- Time (Full range)	p<.001	Dependent
100m	M	Age- Time (20-28 years)	p=.14	Independent
100m	W	Age- Time (Full range)	p<.001	Dependent
100m	W	Age- Time (20-28 years)	p<.001	Dependent
1500m	M	Age- Time (Full range)	p<.001	Dependent
1500m	W	Age- Time (Full range)	p<.001	Dependent
42km	M	Age- Time (Full range)	p<.001	Dependent
42km	W	Age- Time (Full range)	p=0.30	Independent

Table 2

## 100m

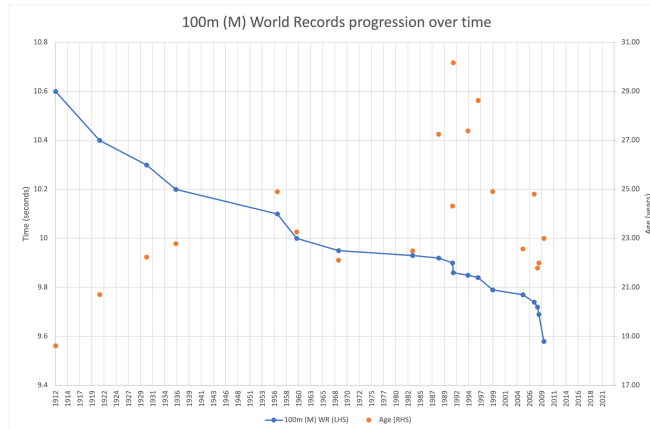


Fig 4: Age of world record holding 100m athletes (men)

The time taken for world record setting athletes to run the 100m sprint is independent of their age for men between 20-28 years old.

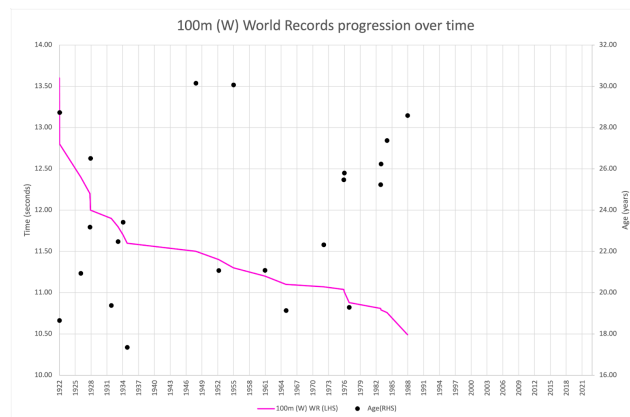


Fig 5: Age of world record holding 100 m athletes (women)

The time taken for world record setting athletes to run the 100 m sprint is dependent on the age of women between 20-28 years old.

The reason that the time taken to run 100 m is dependent of women's age but independent of men's could be that there are multiple possible physiological mechanisms in men for the reduction in the performance sex gap with increasing age, including lower levels of anabolic hormones, a decrease in neuromuscular efficiency, and a reduced ability to synthesize protein as well as body fat. In addition, the loss in skeletal muscle mass is more pronounced in men at the age of 60 years and above compared to women of the same age, with sarcopenia present in ~53% of men compared to ~47% of women.<sup>3</sup>

## 1500m

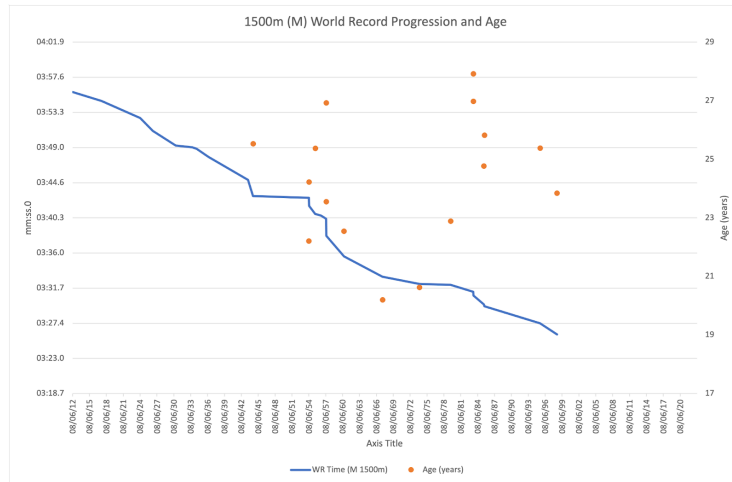


Fig 6: Age of world record holding 1500 m athletes (men)

The time taken for world record setting athletes to run the 1500 m is dependent on their age for men. As the age of athletes increases, so does the time taken to complete the race. The optimal years to run 1500 m for men is between 20 and 28 years old. However, peak performance is loosely defined, and in the context of world records explored in this paper, it may be dependent on when an athlete begins training and racing competitively.

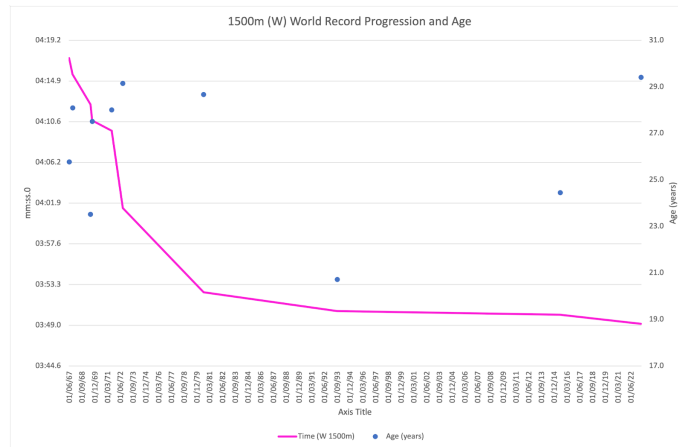


Fig 7: Age of world record holding 1500 m athletes (women)

The time taken for world record setting athletes to run the 1500 m is dependent on their age for women. As the age of athletes increases, so does the time taken to complete the race. The optimal years to run 1500 m for women would be between 20 and 28. Also, fewer world records have been set by women as compared to men since 1967. Age and world record times are weakly correlated, and this finding can be partially justified by the small sample size.



### 42 km (men and women combined)

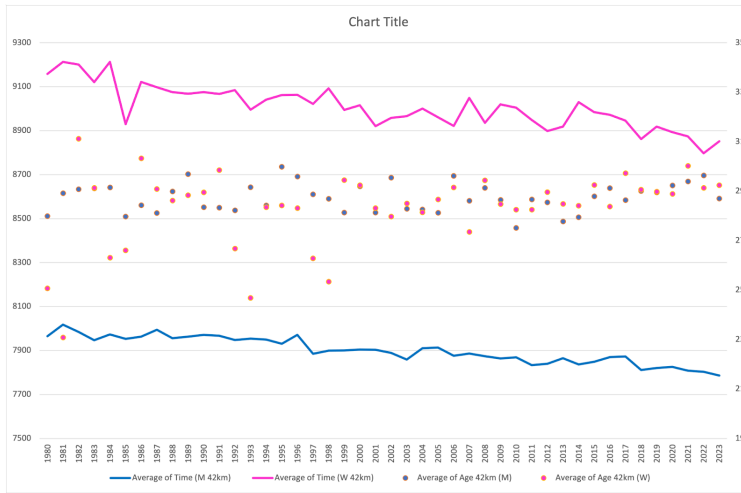


Fig 8: Age of world record holding 42 km athletes

The pink line indicates the average time per year for women, and the blue line indicates average time per year for men. The orange dots indicate the average age of the women, and the grey dots indicate the average age of the men. The time taken for world record setting athletes to run the 42 km is dependent on their age for men.

The time taken for world record setting athletes to run the 42km is independent of their age for women. There is no clear reason or scientific justification for why this is independent, while men's is dependent.

### Performance-100m

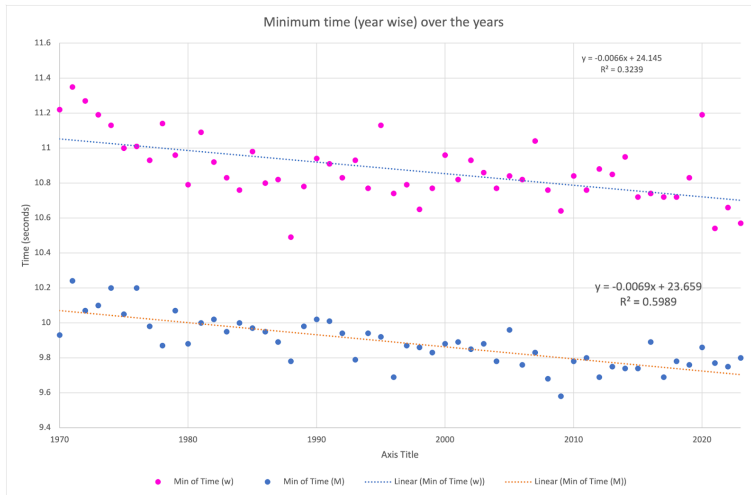


Fig 9: Minimum time per year (100 m)

The graph depicts a negative correlation between year the race was run and time through linear regression analysis. This negative correlation is less pronounced in women compared to men, evident by a shallower slope. The  $r^2$  values reinforce this, indicating a weaker correlation among women. Notably, outliers in the years 1998, 1995, and 2020 deviate from the overall

trend, possibly due to external factors. In summary, the graph shows how the negative correlation differs by gender and highlights the influence of outliers on the relationship between year the race was run and time.

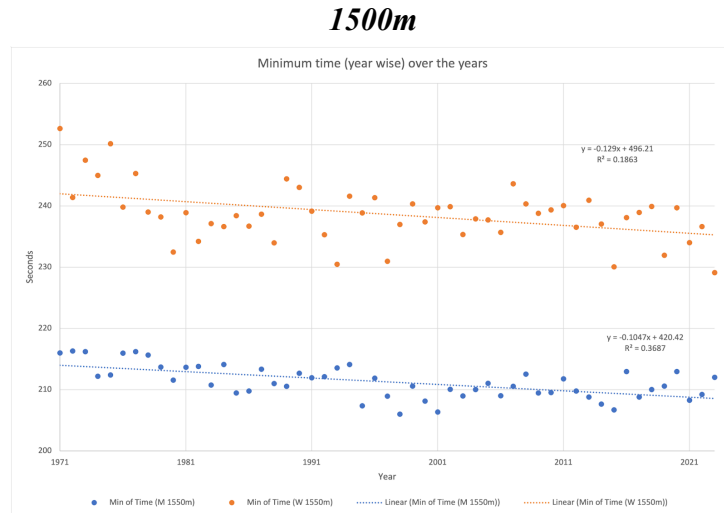


Fig 10: Minimum time per year (1500 m)

The graph depicts a negative correlation between year the race was run and time through linear regression analysis. This negative correlation is less pronounced in women compared to men, evident by a shallower slope. The  $r^2$  values reinforce this, indicating a weaker correlation among women. Thus, the graph shows how the negative correlation differs by gender and highlights the influence of outliers on the relationship between year the race was run and time.

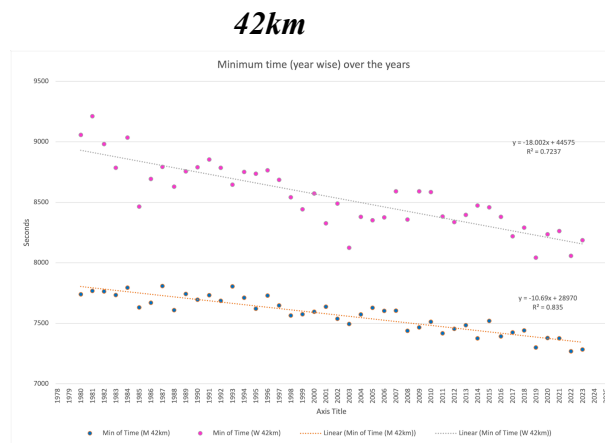


Fig 11: Minimum time per year (42 km)

The graph depicts a negative correlation between year the race was run and time through linear regression analysis. This negative correlation is less pronounced in men compared to women, evident by a shallower slope. The  $r^2$  values reinforce this, indicating a weaker correlation among men. Thus, the graph shows how the negative correlation differs by gender

and highlights the influence of outliers on the relationship between year the race was run and time.

## **Discussion**

All test results were dependent except for 100 m men's race and 42 km women's race, which showed that the time taken to complete the races was independent of their age.

The use of technology in athletics has led to numerous benefits but also elicited criticism. The production of lighter, more aerodynamic, and specialized gear such as carbon-fiber running shoes (e.g. Nike Vaporfly) has been met with skepticism regarding its potential to produce an unequal playing field. Also, the use of wearables and data analytics has provided athletes with substantial data for training, injury prevention, and performance optimization. However, questions about privacy and ethics are often raised in regards to this form of technological assistance. Various techniques such as cryotherapy and hyperbaric chambers have been employed in efforts to improve recovery and physical condition; yet such tools are thought to exclusively favor well-funded athletes and teams.

Looking ahead, virtual reality training, biometric sensors, genetic profiling, and sustainable equipment may be the future of sports technology. Further analysis can be conducted when it comes to nutrition's influence on endurance, diverse shoe types' respective effectiveness in different sports, and divergent training programs' efficacy.

### **Works Cited**

- Cheuvront, S.N., Carter, R., DeRuisseau, K.C. et al. Running Performance Differences between Men and Women. *Sports Med* 35, 1017–1024 (2005).
- “World Athletics Home Page: World Athletics.” *Worldathletics.Org*, [worldathletics.org/](http://worldathletics.org/). Accessed 3 Oct. (2023).
- Waldvogel KJ, Nikolaidis PT, Di Gangi S, Rosemann T, Knechtle B. Women Reduce the Performance Difference to Men with Increasing Age in Ultra-Marathon Running. *Int J Environ Res Public Health* (2019).

# **The Effects of the Covid-19 Pandemic on the Fiscal Health of Social Security's Retirement Fund**

## **By Zach Galitzin**

### **Abstract**

In this research, I explore the effects the Covid-19 pandemic had on the fiscal health of the Social Security's retirement fund. When welfare programs were originally designed, they were meant for a limited number of people that lived for very little time after their retirement. Recently, welfare programs have been expanding to encapsulate tens of millions of recipients, many of whom receive pensions for 20+ years. These increasing costs, coupled with decreasing income due to inflation, are causing immense fiscal pressure on the Social Security Administration. However, Covid-19 had an immense impact on the fiscal flows of the Administration, as it cut lots of revenue through the recession, though it cut costs through the number of deaths as well. In order to quantify the financial impact of Covid, I compiled three figures. First, I display the savings over time from Covid deaths from 2020-2038 (figure 1) to exemplify the longevity of the impact Covid had on the Administration. Next, I examine age group's contribution to the Administration's overall savings (figure 2), which gives insight into why a certain demographic affected savings more than another. Finally, I look at a comparison between a pre-covid trustee report from 2019 and a post-covid trustee report from 2022 (figure 3), and I discuss the difference in projected benefits from 2023-2028. By comparing these two reports, I cover any past limitations with figure 1, as well as showcase the decrease in revenue due to the pandemic. I found that the Covid-19 pandemic served to hurt the Social Security Administration more than it helped them since the costs from the pandemic outweighed the savings from the increased number of deaths.

Keywords: Social Security, beneficiaries, Covid-19, fiscal health/pressure

### **Introduction**

In recent times, governments are under extreme fiscal pressure due to the rapid growth in the number of retirees. With this swift expansion, the Social Security Administration's trust fund is depleting swiftly, meaning it will be unable to cover all of its recipients. (Konnish, 1). Therefore, governments are attempting to reform certain areas of Social Security to alleviate some of the pressure, leading to lots of political opposition. (Lough, 1). On the other hand, the Covid-19 pandemic disproportionately affected the mortality of social security recipients, which plausibly reduced pressure for the Social Security Administration to reform.

It is possible that the pandemic reduced the likelihood of another political riot related to Social Security reform, such as the events taking place in France. Prime minister Emmanuel Macron pushed a bill through parliament to reform their pension system. The central element of the reform is increasing the retirement age from 62 to 64, which means that citizens cannot receive Social Security pensions until they are 64. As a result, hundreds of thousands of upset French workers rioted across France. Despite all of the backlash, Macron decided to

continue with the law and it will go into effect in September 2023. (Lough, 1). These events that took place in France show the potential of violent outbreaks as a result of Social Security reforms. However, the pandemic may have given alleviated some pressure from the Social Security administration, which could give policymakers more time to create legislation around Social Security.

Through this series of events, we see the significance of fiscal pressure on societies. The mere increase of the age by two years incited riots all across France, proving the integral role Social Security has on civilizations. The importance of financial security to them is evident, as it's a safety net that can provide an extra source of income in case of an economic downturn or a lack of funds in retirement. However, the emerging pressure on the trust fund serves as a threat to the fiscal health of Social Security; without it, a nation's economic security could be at risk and many people could fall below the poverty line. Income inequality, homelessness, and social unrest could increase greatly as well.

Covid-19 had a significant impact, and whether its effects were positive or negative is up for debate. It could have completely reshaped the future of the Administration, prolonged its existence or have no impact at all. The answer to this question can frame the future of many elders in America, as well as this nation as a whole.

In this paper, I look at one component of the Social Security Administration's (SSA) fiscal health: the retirement fund. Other financial concerns of the SSA, while no doubt useful to consider, are beyond the scope of this paper. With that in mind, I use publicly available data from the CDC, Social Security Administration, and the Census Bureau pertaining to projected monthly earnings, years of lives lost, number of deaths by age group, to determine the net effect of the pandemic on the SSA. In sum, I find that Covid-19 led to savings of around \$120B. However, comparing trustee reports from 2019 and 2022, it is clear that there is an increase in projected benefits by about \$304B just from 2023-2028. I believe that the Covid-19 pandemic harmed the Social Security Administration, as it reduced the income from tax revenue.

In the following sections, I discuss existing literature and connect it to the pandemic's effect on Social Security. Then I talk through the history of the Administration, as well as how it works. Following that, I document my main results

## **Literature Review**

Gopi Shah Goda and Andrew Biggs document that the SSA has faced a perilous fiscal situation for decades. About 40 years ago, severe inflation worried the Administration. Taxes on wages fund social security. To keep up with inflation of benefit costs, wages needed to rise by the same proportion in the same time period. However, wage rates didn't even match inflation rates, so Social Security faced a large solvency problem. (SSA, 1). As a result, there was a chance they could not pay all scheduled benefits in 1983. They were able to amend short term solvency, and push the depletion of the trust fund back to the mid 2030s. Now, the trustees estimate the depletion to take place in 2034, where the Administration won't be able to pay all of the scheduled benefits. Instead, they are only guaranteed to pay around 80%. The depletion is largely

due to longer life expectancies and decreased fertility rates; these demographic shifts lead to high annual deficits and higher cost per beneficiary. However, the pandemic may serve as a means of lightening the pressure on the Administration, as well as pushing the depletion year back again due to its effects on the elderly population. (Goda, 1)

The pandemic had substantial effects on older generations. According to a study performed by Pierro Poletti, Covid mortality risk increases with age. Among individuals 70 and above, there was a much higher death ratio of 10.5% compared to the 0.43% rate observed from the younger patients. The contrast in ratios highlights a greater susceptibility to mortality among elders than the youth. As a result of the disparity, 907,000 elders passed away due to the pandemic, which was about 80% of the death toll. This literature proves the disproportionate deaths of Covid-19, which largely influences the fiscal health of the Social Security Administration. It's noteworthy that 56% of beneficiaries are retired workers aged 62 and above, precisely the age group with the most Covid-19 deaths. (Poletti, 1)

Further research shows the effect of the pandemic on elderly employment. With the onset of Covid-19, employment among older workers dropped much more compared to predictions before the pandemic. Employment for 51-60 year olds was 8.3% lower than predicted, while 62-70 year olds was 10.7% lower. The cause of the drop in employment is due to increases in unemployment, as well as exiting the labor force. Instead of an increase of Social Security claiming as a result of the mass retirement, the application for benefits remained unchanged. I relate to this literature by examining the effects of Social Security payouts as a result of the increase in retirement, as well as the deaths. (Goda, 1)

### **The Evolution of Social Security**

Not only did the pandemic disproportionately impact the elderly, but the Great Depression also hit them severely. State legislatures attempted to mitigate the effects of the downturn by implementing pension plans, though many were failures due to underfunding and negligence. Officials and citizens tried to enforce plans to increase economic security, mostly federal pensions, but the officials were vehemently opposed to such an idea until Franklin Roosevelt entered office. He took inspiration from Europe's economic security plans and later created the Committee on Economic Security. The committee created the Social Security Act, passed in 1935. (SSA, 1)

Initially, the Social Security Act was rather bare and didn't include any coverage for healthcare or disabilities; it only counted for old-age assistance. It worked by citizens contributing to a payroll tax, which was stored in a trust fund. The Social Security trust funds store money for costs that are not in use, like benefits or administrative costs. They are invested in treasury bonds guaranteed by the government. The money from the trust fund was distributed in lump sums to those who applied when they turned 65. It took about 3 years for the Administration to use monthly pensions instead. The pensions they received were based on a proportion of income, tracked by a Social Security number. (SSA, 1)

The following 20 years of Social Security were very eventful, with many significant amendments. The 1939 amendments made the Administration more inclusive: they gave pensions to people dependent on the elderly, such as spouses and children, and survivor benefits paid to the family of a prematurely deceased elder. However, the new increased recipients required a lot more money, and the pensions weren't meeting the financial needs of the beneficiaries. The government introduced the cost of living adjustment (COLA) to address this, increasing pension values. (SSA, 1)

Over time, the program expanded to facilitate many different needs of its recipients, such as disability insurance and Medicare. Additionally, the Administration accounted for many more people since the Administration lowered the retirement age from 65 to 62. Social Security was becoming very expensive due to its number of beneficiaries, and the state governments were not able to handle all of the payments; therefore, the federal government assumed the adult categories (elderly over 65, and disabled elder) by creating the Social Security Income program and assigned responsibility to SSA. (SSA, 1)

Today, the Social Security Administration has become essential to the lives of many, with about one in seven people receiving pensions, and 90% of jobs covering Social Security. However, people live much longer now than the 1930s, so the Administration has to give out much more money. Additionally, their massive expansion became a source of fiscal pressure. They started encapsulating many demographics, boosting the number of recipients beyond what they can reasonably handle. Furthermore, there were many pension increases with the addition of COLA, furthering the pressure on the trust funds. As a result, Social Security has been faced with solvency issues for decades now, as they have far more recipients that cost much more than 80 years ago. (SSA, 1)

### **Social Security Operations**

During working years, all employees, employers, and self-employed individuals contribute to a Social Security payroll tax, stored into one of two trust funds: the Old Age and Survivors fund and the Disability Insurance fund. When a worker stops receiving money through their labor, the worker is eligible for monthly benefits until death, distributed at a discount rate of 3% a year. These recipients are split into three categories: retirement benefits, survivor benefits, and disability benefits. (SSA, 1)

A worker is eligible for retirement benefits by working somewhere covered by Social Security. In order to qualify for benefits, one must work for at least 10 years. (SSA, 1). When a worker meets these requirements and is above 62, they can receive benefits, which are based on their highest paying 35 years of work. However, recipients at 62 receive benefits at a reduced rate. These benefits are known as early, since pensions are collected before the current normal retirement age of 67. 36 months before the normal retirement age, benefits are reduced by 5/9 of one percent; every month that exceeds 36 is further reduced to 5/12 of one percent. At 67, the recipient will receive their benefits in full. (SSA, 1). Additionally, retirement benefits are extended to wives or dependent husbands 62 or above, children under age 18 or older children



who became disabled before 18, and a wife of any child eligible for benefits. (SSA, 1). Because the retirement fund is concentrated towards the elderly, Covid-19 affected the old age trust fund much more as the deaths were disproportionate toward them.

Survivor and disability benefits are issued to certain family members of a prematurely deceased recipient: surviving widow or dependent widower over 62, children under 18 or disabled before 18, a mother of a disabled child, and dependent parents over 62. A lump-sum death payment is issued as well. Furthermore, Disability benefits are monthly pensions for those who are permanently disabled and to the same dependents as retirement benefits. Many elders passed away during Covid, so the amount survivor benefits were quite high; though the amount disability benefits were not as high. However, both of these are outside the scope of this paper. (SSA, 1)

### **Adding Up the Effects of the Pandemic**

In the following section, I discuss the data and detail the calculations that I use to get my results, as well as the underlying assumptions.

### **Methodology**

First, I gathered my data through publicly available sources. I used the CDC’s website on the total death count for all Covid-19 deaths in the U.S. (CDC, 1). Additionally, I found the years lost per age due to Covid-19 as well as annual projections for 2020-2044 through the Social Security Administration. (SSA, 1). Finally, the Census Bureau provided me with the population per age.

I split up the age cohorts based on the CDC’s website, though I cut it off at 62 since no benefits are given out before then. To get the most accurate estimate of years the entire cohort had left to live, I took the weighted average of population per group, and multiplied their percentage by their years left to live. The summation of their weighted years left brought me to the entire cohort’s years left to live.

Table 1

Age groups	Years remaining
62-64	18.64
65-74	14.15
75-84	8.41
85+	2.11

After that, I took the annual projections for retirement benefits from 2020-2038 from Social Security’s website, and discounted them at a real interest rate of 1% to present value. This accounts for 2% expected inflation. To find the amount Social Security owed per person, I summed all of these discounted values for every age cohort based on their years lost. Multiplying the amount owed per person by the amount of deaths for every age cohort gave me the amount saved in that age group. Following that, I simply added up each value to arrive at the total amount saved: \$117,667,904,648

**Assumptions**

However, I made some assumptions to get to this number. I assumed that every one of these adults were going to Social Security, and they were all going to collect at the early retirement age of 62. Additionally, I figured that everyone would receive the same amount of pensions based on average annual projections, in reality everyone would receive pensions based on their most successful 35 years of work. Also, I assumed that all of them would have died on their presumed death year by the years lost from Social Security, and none of them died early. I made assumptions about the solvency of Social Security: I believed it would be stable through 2020-2044, without complete depletion of the trust fund.

**Figure 1**

This graph describes savings over time for Social Security, starting in 2020 and ending in 2038. The summation of all the years equals \$117,667,904,648, which is the amount the Administration saved due to elderly mortality. Figure 1 exemplifies the evolution of savings, specifically how Covid-19 affects the Administration in the long run.

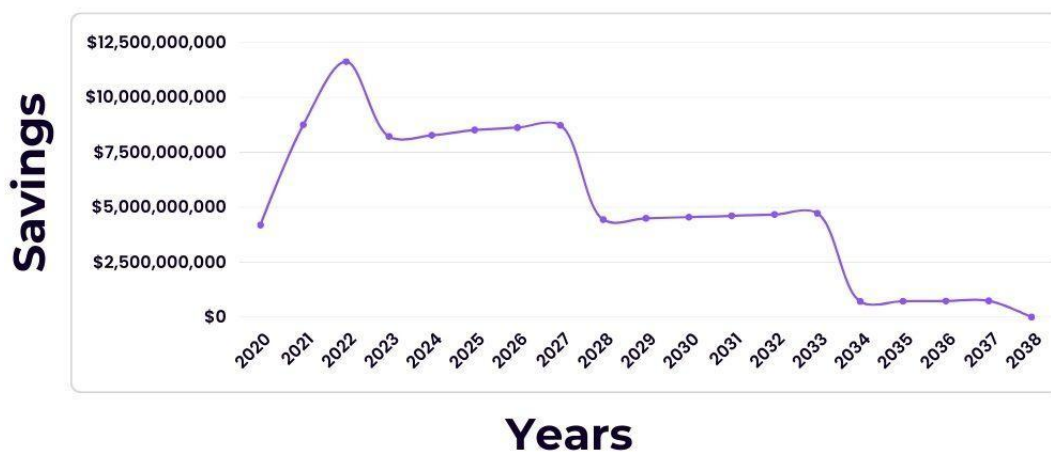


Fig 1: Graph of the Social Security Administration’s savings over time. Data was compiled from Social Security Administration, Central for Disease Control, and Census Bureau. Deaths were sorted into 4 age groups, and a weighted average of years remaining was found for each cohort. Each year that the individual would have been collecting pensions was added up until the

individual supposedly died. That number was multiplied by number of deaths, which was the amount saved per cohort

There were many limitations in making figure 1. It does not account for both of the trust funds, rather just the retirement fund since that's what was affected by the disproportionate deaths by the pandemic. Additionally, there is no account for the deaths of those who contributed to the payroll tax, which would have altered the benefit to the people as well as the income for the Administration. The deaths could've been leveled out from the increase in the labor force participation rate as well. Furthermore, the 85+ cohort includes many who are 100+, who are much more likely to die sooner than someone who's 85.

According to the graph, the savings from covid is expected to decrease overtime, as the Social Security Administration owes less money to people. Also, by discounting to present value, the value of money mechanically decreases over time. There is a sharp increase in savings from 2020-2022 due to the large rise in mortality among the elderly; then, the number of deaths slows down in 2023. Additionally, there's a spike downwards in 2022, primarily because individuals aged 85+ only have two years remaining to live, so the Administration doesn't owe them any money past 2022 in expectation. From 2023-2028, the savings slowly increases since there's an increase in wages, though falls sharply again as those aged 75-84 are projected to pass away, and they made up most of the beneficiaries. Savings are relatively stagnant until 2034, where 65-74 year olds expect to pass away, again reducing a large chunk from the amount Social Security must payout.

Each of the age groups contributed a sum of the savings to the administration, though when they reached their projected death year, the government no longer owed them any money. When these death years took place, savings dropped heavily, though the contributions were unequal. For example, 75-84 year olds contributed much more than 85+ year olds since they weren't expected to live as long.

## Figure 2

Next, I break down the contributions to savings from each group. I aim to describe how the difference in demographics impacted the contributions, which allows examination into exactly why a certain age group affected savings more than another.

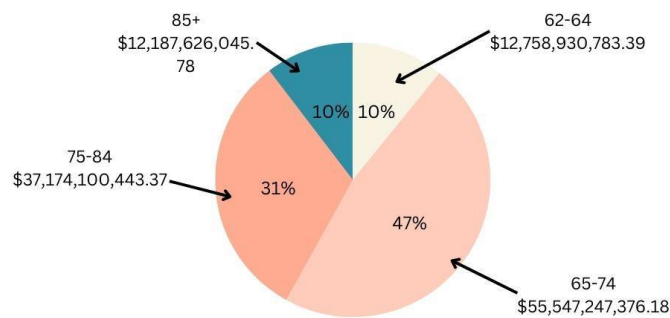


Fig 2: The demographics that received Social Security pensions. The percentage of savings per age cohort to Social Security's savings was found by adding up each year of savings per

individual then multiplying it by number of deaths to find how much was in each cohort, then finding that number's percentage to overall savings.

The Social Security Administration's savings is closely tied with age of recipients; the older they get, the less money the government owes them. 65-74 year olds contributed about half of the savings as the government owed them a lot of money, about \$217,366 per person at 255,547 deaths. Additionally, they had about 14 years left to live, so the Administration would've owed them money for another 14 years. Their large contribution is likely due to their cost per person combined with their high mortality rate for 14 years. 65-74 year olds were followed behind those aged 75-84, who didn't cost as much as the 65-74 year olds at \$124,793 per person, but they had a higher mortality rate at 297,885 deaths. Though, they weren't expected to live much longer, only 8 more years. Finally, 85+ year olds and 62-64 year olds were comparable in their contributions since those aged 85+ had 309,017 deaths, but only had two years left to live, so their cost was very low. 62-64 year olds cost the most since they were expected to live for 18 more years, but had the least amount of deaths with 45,071.

All three factors of cost per person, number of deaths, and years remaining until death were important to contributing to the savings, though a noticeable trend is the inverse relationship between deaths and cost, as one would expect a cohort with a large amount of deaths cost the most. However, contributions mostly depended on the relationship between years left to live and number of deaths.

**Figure 3**

Since figure 1 didn't capture all the costs and income of the retirement fund over Covid, I compiled a figure that depicts the difference in pre-Covid projected benefits from 2019 and post-Covid 2022 projected benefits, from 2023-2028. These numbers cover all the costs and income for Social Security that I didn't account for, and shows the impact that all the death during Covid-19 on the administration.

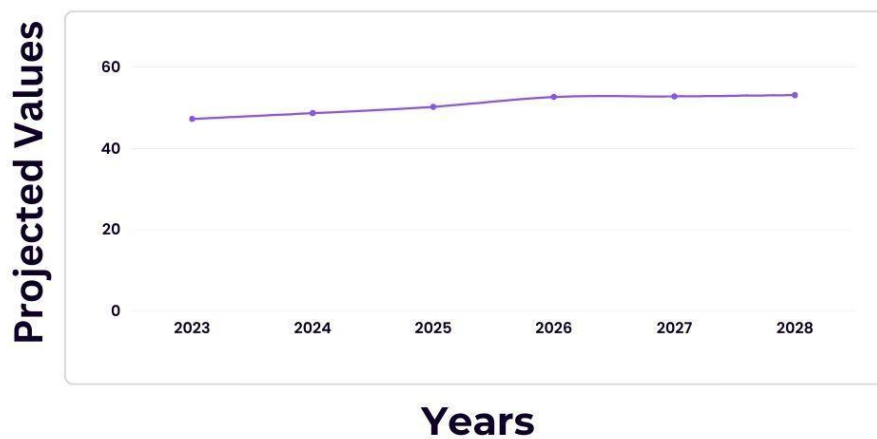


Fig 3: The difference in projected pension payments in billions from 2019 and 2022. Data was compiled from the Social Security Administration for projected pension payments from

2023-2028 during the years 2022 and 2019. These values were subtracted to see the overall change in projected payments for 2019-2022.

The average difference in projected benefits between 2019 and 2022 is about \$50.76 billion, which slightly increases from 2023-2026, though is relatively stagnant afterwards. Summing all the years gets the total difference, which is about \$304 billion. Though, figure 3 displays an increased cost to the Administration, while figure 1 shows an increase in savings. Additionally, the amount saved from 2023-2028 in figure 1 is \$46,781,097,612, so the impact deaths had on the fiscal health of Social Security was rather miniscule compared to the cost caused by the pandemic.

My numbers and Social Security's numbers are much different since I only accounted for death's impact on the Administration, while their numbers include all factors pertaining to the retirement fund. However, it's interesting that the pandemic cost the Administration much more than it saved it, which is due to the loss in payroll tax revenue from the recession in the beginning of 2020. The deep recession outweighed any savings pertaining mortality among the elderly, since employment, interest rates, and economic growth fell steeply. (Press, 1). Additionally, the Administration is faced with the same problem now from the 1980s, we are faced with a rising inflation, but wages are not matching. As a result, the income to the Administration is simply not worth as much. (Konnish, 1).

## **Conclusion**

With these findings, the pandemic's impact on Social Security's future seems to be more grim than expected. It's intuitive to believe that the deaths from all of the elderly would've been beneficial to the fiscal health of the Administration, though the pandemic caused an increase in projected benefits by \$304 billion, with the already increasing fiscal pressure due to increased retirement among the baby boomer generation. The mortality from Covid didn't have enough of an impact to dwindle the effects of the loss in revenue from the recession, so the pandemic seemed to harm the Administration more than it helped it.

My contribution to Covid's effect on Social Security is displaying the effect deaths had on the administration. Savings from the pandemic was around \$117 billion dollars, which would have culminated across 18 years. The contribution to savings was concentrated among those aged 65-74 since they had a high mortality rate, and they cost the most, while 85+ and 62-64 year old contributed the least due to their imbalance in cost and deaths.

It's clear that the impacts pandemics have on social welfare are bigger than the deaths of the elderly, there are many more aspects that must be accounted for, such as increased benefits due to the pandemic, decrease in income, increase retirement, etc. We can use covid-19 as an example to be much more prepared in the wake of another pandemic.

## Works Cited

- Biggs, Andrew G., and Gopi Shah Goda. *Strengthening the Social Security Safety Net*. Apr. 2023. *policycommons.net*,  
<https://policycommons.net/artifacts/3531879/strengthening-the-social-security-safety-net/4333017/>.
- COVID Recession Pushed Social Security Insolvency Up A Year* : NPR.  
<https://www.npr.org/2021/09/01/1033151631/a-new-report-says-the-covid-recession-has-pushed-social-security-insolvency-up-a>. Accessed 4 Oct. 2023.
- Goda, Gopi Shah, et al. “The Impact of Covid-19 on Older Workers’ Employment and Social Security Spillovers.” *Journal of Population Economics*, vol. 36, no. 2, Apr. 2023, pp. 813–46. *Springer Link*, <https://doi.org/10.1007/s00148-022-00915-z>.
- Konish, Lorie. “Social Security Trust Funds Depletion Date Moves One Year Earlier to 2034, Treasury Says.” *CNBC*, 31 Mar. 2023,  
<https://www.cnbc.com/2023/03/31/social-security-trust-funds-depletion-date-moves-up-to-2034.html>.
- Lough, Richard. “Explainer: Why Is Macron in so Much Trouble over Pension Reform?” *Reuters*, 20 Mar. 2023. *www.reuters.com*,  
<https://www.reuters.com/world/europe/why-is-macron-so-much-trouble-over-pension-reform-2023-03-20/>.
- Poletti, Piero, et al. “Age-Specific SARS-CoV-2 Infection Fatality Ratio and Associated Risk Factors, Italy, February to April 2020.” *Eurosurveillance*, vol. 25, no. 31, Aug. 2020, p. 2001383. *PubMed Central*, <https://doi.org/10.2807/1560-7917.ES.2020.25.31.2001383>.
- “SIEPR Policy Brief April 2023.” *Google Docs*,  
[https://drive.google.com/file/d/1t9LqKk7Ly1VeIYSqmNUzGo9n4szNumyO/view?usp=sharing&usp=embed\\_facebook](https://drive.google.com/file/d/1t9LqKk7Ly1VeIYSqmNUzGo9n4szNumyO/view?usp=sharing&usp=embed_facebook). Accessed 4 Oct. 2023.
- Social Security History*. <https://www.ssa.gov/history/2000.html>. Accessed 4 Oct. 2023.
- Social Security History*. <https://www.ssa.gov/history/notchfile1.html> . Accessed 4 Oct. 2023.
- Social Security History*. <https://www.ssa.gov/history/briefhistory3.html>. Accessed 4 Oct. 2023.

# Air Intake Adjustment Device Applied to Negative Pressure Gas Radiant Heating Equipment By Siteng Wang

## Abstract

Infrared radiant heating systems, especially those utilizing negative pressure combustion, have become increasingly popular for large domestic spaces due to their energy efficiency and immediate impact on thermal comfort. However, these systems pose operational challenges, particularly when adjusting the air intake for individual burners in multi-burner configurations. This paper introduces a novel air intake adjustment device designed to streamline this adjustment process. Developed through meticulous CAD conceptualization and iterative prototyping, the device offers an adjustment range restricting 0-50% of air intake. Empirical evaluations reveal a significant reduction in debugging time and maintenance demands, hinting at potential enhanced energy efficiency. The invention, which has been patented in China and is under review in the United States, represents a pivotal advancement in radiant heating technology. Through its innovative design, this device not only addresses operational challenges but also paves the way for a more sustainable and energy-efficient future in heating systems.

## 1. Introduction

### 1.1 Background of Radiant Heating Systems

Infrared radiant heating has become increasingly popular for warming large domestic spaces. [1] The use of infrared heaters in a workplace provides heating systems with low energy intensity and an immediate effect on thermal comfort. [2] When compared with other heating systems, they offer the substantial advantage of greater energy efficiency. Particularly prevalent are unit-type tubular radiant heaters, which are employed due to their efficiency and ability to provide consistent heating [3]. These heaters can be categorized based on their combustion method into positively and negatively pressurized systems. Examples of typical infrared heaters are shown below in figure 1 and 2.



Fig 1: a typical vacuum heater with heat tubes attached.

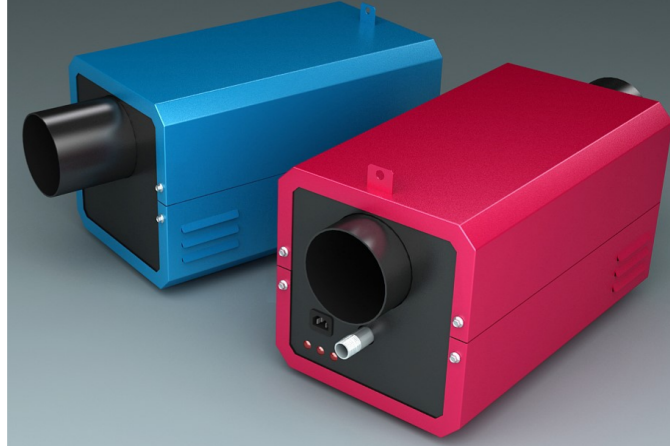


Fig 2: the component of the heater where combustion takes place

### 1.2 Challenges in Current Systems

Current radiant heating systems, especially those with negative pressure combustion, pose several operational challenges. For a single unit, the factory calibrates the air and gas intake proportions precisely. However, when multiple burners are used in a system as shown in figure 3, adjustments become more complex and labor-intensive.

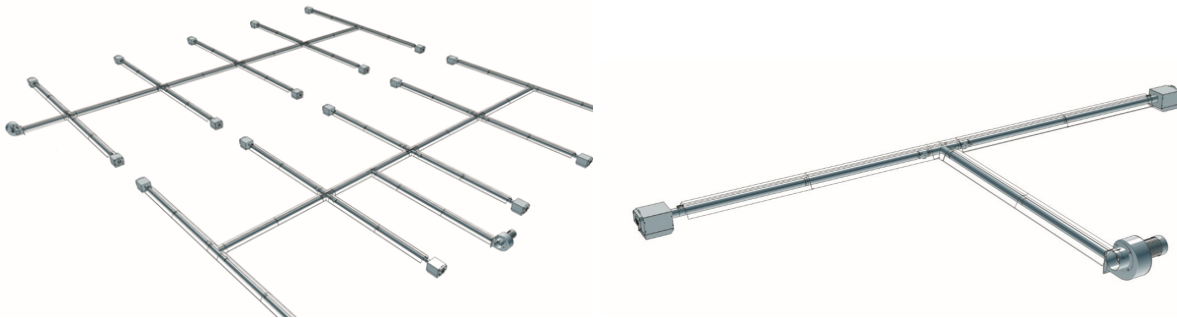


Fig 3: Configurations of different numbers of burners (10 and 2)

To modify the air intake for individual burners in these systems, it becomes necessary to install adjustment valves in each branch of the radiation tube, as shown in figure 4. The adjustment process requires a coordinated effort among several individuals: one person must modify a wind valve while others must monitor various burners' operating conditions. Given the differing distances from each burner to the fan and the variations in wind pipe resistance, it is challenging to set a uniform opening for all the wind valves. Adjusting one wind valve can inadvertently alter the air intake for other burners, requiring constant monitoring and re-adjustment by multiple personnel.



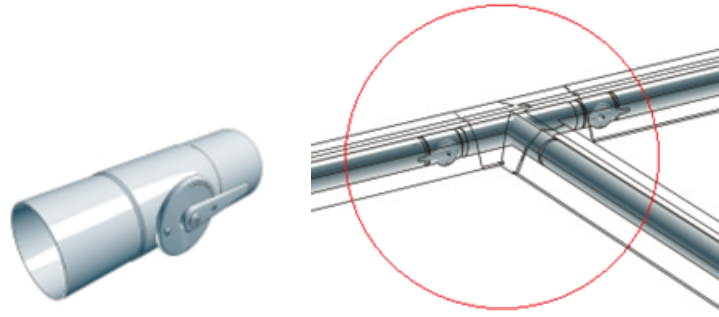


Fig 4: (left) shows an adjustment valve, (right) shows the placement of them at the intersection

### **1.3 Objective of the Invention**

Considering the above challenges, this invention aims to introduce a simplified and efficient solution. The objective of this invention is to create an air intake adjustment device that is easy to operate and can be applied to the burners of various negative pressure infrared gas radiant heating systems. This device is designed to eliminate the need for multiple personnel to coordinate efforts during the adjustment process, offering a more streamlined and effective approach to air intake regulation.

## **2. Development Process**

### **2.1. Initial Conceptualization**

The idea for the air intake adjustment device was initially conceptualized using CAD software. This digital representation allowed for a precise and detailed envisioning of the product's design, ensuring that the subsequent physical models would be both functional and effective.

### **2.2. Prototyping and Iteration**

With the digital model as a blueprint, the first physical prototype was crafted using sheet metals. This prototype provided a tangible representation of the device and served as a basis for real-world testing and evaluation. The design allowed for an adjustment range that could restrict 0-50% of the air intake, providing users with a versatile control mechanism tailored to their specific needs. Figure 5 below showcases the prototype design with the setting set to 0%, showing the starting point of its adjustment range.



Fig 5: The prototype design, set to 0%

Upon evaluating the initial prototype, several iterations were carried out. These iterative processes involved making minor adjustments to the design, refining its functionality, and ensuring optimal performance. The final design retained the 0-50% adjustment range, optimizing its mechanism for ease of use and precision.

### 2.3. Finalization and Production

After multiple iterations and refinements, the final design of the air intake adjustment device was settled upon. To seamlessly integrate the device with the burner system, the device was painted to match the color of the burner. This not only improved its aesthetic appeal but also ensured that it blended effortlessly with the existing heating system. Figure 6 demonstrates the final design with the setting adjusted to 50%.



Fig 6: Final design, set to 50%

### 2.4. Patent Status

The innovation behind the air intake adjustment device has garnered formal recognition. The invention has been granted a patent in China, affirming its unique design and functionality.

Additionally, the patent application is currently under review in the United States, awaiting approval.

### 3. Design and Components of the Air Intake Adjustment Device

#### 3.1 Major Components

The air intake adjustment device consists of two primary components:

1. **Intake Cover:** This is a critical element of the device, designed to hold the plate which regulates the volume of air entering the gas burner. This cover is designed to function with the Intake Adjustment Plate. Shown in Figure 7.
2. **Intake Adjustment Plate:** This component is the dynamic element of the device. By turning the air volume adjustment plate, the air intake of the burner can be precisely controlled, allowing for easy adjustments as per the requirements of the heating system. Shown in figure 8 (left)

These two components are designed to work in harmony, creating a seamless and effective means of adjusting the air intake in a negative pressure gas radiant heating system.

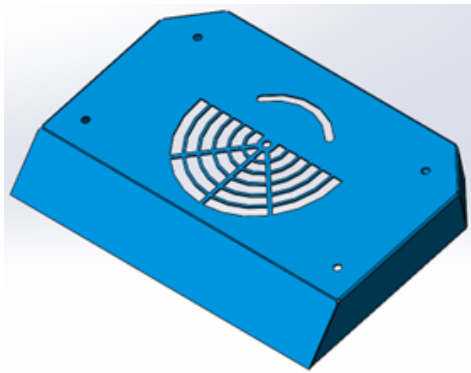


Fig 7: Intake Cover

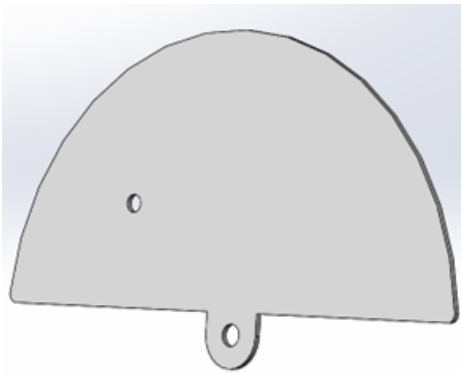
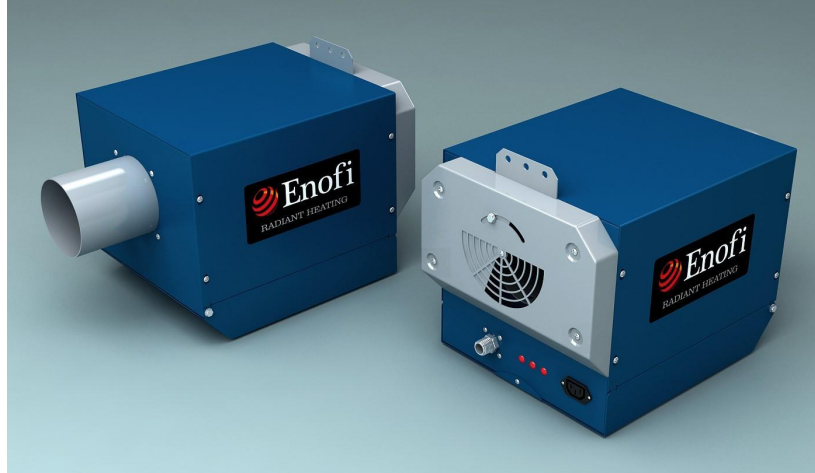


Fig 8: Intake Adjustment Plate

#### 3.2 Integration and Installation

To install the air intake adjustment device, the intake adjustment plate is first securely attached to the intake cover. Following this, the intake cover can be screwed onto the intake of the burner. The installation process is designed to be simple and straightforward, minimizing the need for specialized tools or extensive technical knowledge. Figure 9 is a render which demonstrates what the intake looks like once installed onto the burner.



[Figure 9]

## 4. Working Principle of the Device

### 4.1 Adjustment Mechanism

The core function of the air intake adjustment device lies in its ability to precisely regulate the air intake of a gas burner in a negative pressure radiant heating system. This is achieved through the interaction of the two main components.

When the intake adjustment plate is turned, it alters the size of the opening that is exposed to the incoming air. This action thus provides a mechanism to finely tune the volume of air that is drawn into the burner, thereby enabling the user to finely tune the air-to-fuel ratio for optimal combustion, and cuts down on the amount of time and personnel that's needed during maintenance. This turning action is simple, intuitive, and can be performed without the need for special tools or extensive training.

### 4.2 Adaptability

One of the key strengths of this device is its adaptability to a wide variety of negative pressure gas radiant heating systems. This adaptability is achieved through the design of the intake cover. The size of this cover can be altered to suit the specifications of various brands and models of burners, thereby ensuring that the device can be effectively integrated into diverse heating systems, making it a practical solution for a wide array of negative pressure infrared gas radiant heating systems.

This design consideration means that the device is not only effective in its primary function of adjusting air intake but is also versatile and universally applicable.

## 5. Empirical Evaluation

### 5.1 Methodology

To assess the efficacy of the air intake adjustment device, comparative tests were conducted. These tests were designed to evaluate the performance of negative pressure gas radiant heating systems with and without the implementation of the air intake adjustment device.

Key metrics of interest in these tests included the time spent on debugging the systems and the stability of burner operation during prolonged use. To ensure the reliability of the comparative data, the comparisons are done on projects with the same amount of burners and the same installation/maintenance crew.

## 5.2 Results

### 5.2.1 Debugging Time Comparison

A significant reduction in debugging time was observed when the air intake adjustment device was implemented. Figure 10 depicting this comparison illustrates a clear trend towards reduced time and effort needed for system calibration and adjustment with the device in place.

Equipment type	Comparison one				Comparison two			
	Number of burners	Number of vacuum	Number of workers / lifting platforms	Debugging time	Number of burners	Number of fans	Number of workers / lifting platforms	Debugging time
Equipment without air intake adjustment device	36	9	6/3	18.5h	120	30	6/3	59.7h
Equipment with air intake adjustment device	36	9	1/1	6.3h	120	30	2/2	13.4h

Fig 10: Comparing debugging time for equipment with and without intake adjustment device

### 5.2.2 Operation Results Comparison

In addition to the reduction in debugging time, figure 11 demonstrates the air intake adjustment device's capacity to stabilize the operation of the burners over an extended period.

And when recalibrations are needed, systems equipped with the air intake adjustment device require less time spent on after-sale servicing, highlighting the device’s positive impact on long-term system stability and reliability.

Equipment type	Comparison three				Comparison four			
	Number of burners	Number of vacuums	Number of recalibrations needed.	Time spent on post-sale services	Number of burners	Number of vacuums	Number of recalibrations needed.	Time spent on post-sale services
Equipment without air intake adjustment device	36	9	6	10.8h	120	30	30	39.7h
Equipment with air intake adjustment device	36	9	1	1.5h	120	30	3	5.0h

Fig 11: Comparing time spent on post-sale services for equipment with and without intake adjustment device

### 5.3 Discussion

The comparative tests indicate that the air intake adjustment device offers substantial operational advantages. Primarily, the device dramatically reduces the time and manpower required for debugging negative pressure gas radiant heating systems. This reduction in debugging time translates into lower initial setup costs, faster system deployment, and less uses of lifting platforms.

Moreover, the tests reveal that systems utilizing the air intake adjustment device exhibit more stable and reliable operation over extended periods. This is evident from the reduced malfunctions and reduced time for post-sale servicing, which is a clear indicator of the device's effectiveness in maintaining optimal burner conditions. As such, the device not only simplifies

the initial setup of radiant heating systems but also contributes to more consistent and efficient long-term operation.

This data strongly suggests that the air intake adjustment device is a practical and valuable addition to negative pressure gas radiant heating systems, offering both immediate and ongoing benefits.

## **6. Conclusion**

### **6.1 Summary of Invention and Findings**

The development and implementation of the air intake adjustment device have addressed prominent operational challenges within negative pressure gas radiant heating systems. From the conceptualization through various stages of prototyping and iterations, to the final patented product, the journey of invention has been marked by meticulous design and adaptation. The empirical evaluations underscore its efficacy, showcasing not only a significant reduction in debugging time and maintenance demands but also hinting at its potential for enhanced energy efficiency.

### **6.2 Future Work**

While the invention has proven its merit, future endeavors could explore:

- **Further Optimization of Component Design:** Enhancing the design for broader compatibility and perhaps even greater efficiency.
- **Long-term Durability Testing:** Ensuring the device's robustness and reliability across extensive use.
- **Integration with Smart Control Systems:** Enabling remote or automated adjustments to the air intake, providing even more user-friendly and precise control.
- **Assessment of Environmental Impact:** Quantifying the environmental benefits brought about by possible improved combustion efficiency.

### **6.3 Final Remarks**

The air intake adjustment device stands out as a pivotal innovation in radiant heating technology, weaving through complex engineering challenges to provide a simple, effective solution. Its development, deeply rooted in thoughtful design and iterative refinement, has yielded a device that not only elevates the efficiency and manageability of radiant heating systems but also paves the way towards energy-conscious and sustainable technological advancements. This invention is not merely a technical convenience; it symbolizes a stride towards a more energy-efficient and sustainable future in heating technologies.

### Work Cited

- R. Hu, J.L. Niu. A review of the application of radiant cooling & heating systems in Mainland China, *Energy and Buildings*, Volume 52, 2012, Pages 11-19.
- Petras D, Kalus D. Effect of thermal comfort/discomfort due to infrared heaters installed at workplaces in industrial buildings. *Indoor and Built Environment*, 2000;9:148-156.
- Roth, K., Dieckmann, J., & Brodrick, J. (2007). Infrared radiant heaters. *ASHRAE Journal*, 49(6), 72-73. Retrieved from <https://www.proquest.com/scholarly-journals/infrared-radiant-heaters/docview/22045755/3/se-2>



# **Determining if There are Genes that Contribute to the Comorbidity of Generalized Anxiety Disorder and Attention Deficit Hyperactivity Disorder By Anh Nguyen**

## **Abstract**

Attention Deficit Hyperactivity Disorder (ADHD) has been prevalent for many years and is one of the most researched neurological/neurodevelopmental disorders. Although the cause(s) for ADHD are still unidentified, recent research has shown that genetics can play a key contributing role. ADHD tends to be diagnosed during childhood but the disability can be carried on well into adulthood. Similarly, Generalized Anxiety Disorder (GAD) is another very common mental disorder and can also be diagnosed during childhood. Anxiety disorders involve dysfunction in brain circuits that respond to danger. GAD and ADHD have a significant impact on the lives of many patients around the world who suffer from both conditions. The purpose of this research paper is 1) to demonstrate that these two disorders can be comorbid 2) to show that the risk of the disorders can be influenced by genetic factors and 3) how gene editing such as CRISPR can be used for treatment. Recent genetic studies have found a link between the two disorders, however, although there is a direct correlation between ADHD and GAD, it does not imply a direct causation between the two. Findings suggest that the development of comorbidity stems from the symptoms of ADHD which may lead to the development of GAD. There have been studies conducted in an attempt to identify genes associated with ADHD and GAD but the results have been fairly inconsistent and researchers have not been able to duplicate findings in many studies.

## **Introduction**

ADHD and GAD are among the most prevalent and impactful psychiatric diseases. While each disorder can not be centralized to one cause, there is no question as to whether or not genetics plays an important role in the development of ADHD and GAD. GAD has a heritability rate of about 31.6% (Gottschalk and Domschke) and the genetic influence surrounding ADHD ranges from 77%-88% (Faraone and Larsson). This study will focus on the comorbidity of ADHD and GAD.

Both disorders are commonly confused with other conditions, but in actuality, they have their own distinct functions which can lead to difficulties in everyday functions. GAD is characterized by persistent and excessive worry. This can apply to a person's social, work, or personal problems where they experience extreme uncontrollable distress or catastrophizing of events that don't warrant the specific reaction. It is often confused with just feelings of anxiousness, but concerning GAD, the feelings of worry do not mainly come from a stressor and it span over extended periods of time. The disorder affects approximately 5% of the adult population, and it is twice as prevalent in women than in men (Davies et al.). Anxiety disorders are characterized by numerous neuroendocrine, neurotransmitter, and neuroanatomical disruptions. When studying the brains of patients who were diagnosed with GAD, there were high ratios of gray matter to white matter in the upper temporal lobe and increased amygdala

volume. The amygdala has been studied heavily as it plays an important role in the fear response, and it may be controlling the inaccurate interpretations of social behavior in people with GAD (Martin et al.). A trial had also been conducted linking autonomic hyperarousal with regulatory dysfunctions in the vmPFC. During the study, the participants had decreased activity in the ventromedial prefrontal cortex, which is part of the brain responsible for generating feelings of fear and safety (Teed et al.). GAD along with other psychological disorders such as Major Depressive Disorder (MDD) have translated into health issues specifically in the gastrointestinal system. The patients presented with high comorbidity of any anxiety disorder at 64.6% (nearly two-thirds) of the group although the exact cause had not been determined as there are numerous biological factors that can be considered (Söderquist et al.). There are numerous impairments to one's quality of life when living with GAD. When taking surveys of an individual's subjective assessment of their own quality of life, they reported less satisfaction with their life compared to subjects not diagnosed with an anxiety disorder (Barrera and Norton). Specifically, individuals reported significant impairments at work and social functioning, and lower quality of life than non-anxious controls, such as self-esteem, goals, money, and friends (Henning et al.).

ADHD is characterized by inattention, being unable to maintain focus, hyperactivity, excessive movement, and impulsive behavior, actions made without proper thought [9]. ADHD can harm a child's self-esteem as it increases their chances of criticism and decreases their socializing abilities. If ADHD remains untreated it can be detrimental to one's abilities, including academic achievement and the formation of personal relationships (Wilens and Spencer). It is critical that established research is conducted about the inner workings of ADHD because it is one of the most prevalent neurodevelopmental disorders with a prevalence rate of 5% in children, and of those, 65% of them continue to have ADHD persist into their adulthood (Gehricke). However, the study was conducted to interpret the brain anatomy of ADHD which came to the conclusion that diagnoses were consistent with widespread micro and macro structural changes in the frontal, basal ganglia, anterior cingulate, temporal, and parietal occipital regions. There were also signs of there being involvement in the superior longitudinal fasciculus and corto-limbic areas which could be contributors to audio-visual, motivational, and emotional dysfunctions that are consistent in patients with ADHD (Gehricke). Diagnosing ADHD can be extremely difficult because some symptoms that exist within ADHD can be presented as social, generalized, or panic-like symptoms, which is why it can often go unnoticed (Wilens and Spencer). Additionally, ADHD is associated with numerous health risks that result in patients having double the health care costs. Specifically, individuals with ADHD are 1.5 times more likely to develop an addiction to substances, have higher rates of obesity, are 3 times more likely to binge eat, and are associated with unsafe sexual behavior (Schoenfelder and Kollins).

### **Genome-Wide Association Studies (GWAS)**

Genome-wide association Studies (GWAS) is a method of determining potential genetic variants that can be associated with a number of complex diseases by comparing sets of DNA among multiple people. The information found on genetic variations is then used to develop

more specialized methods of detecting, treating, and preventing the disease (Genome-Wide Association Studies).

Numerous GWAS have been done in pursuit of searching for variants that could be contributing to the development of ADHD, however, none of them had reached genome-wide significance or had suggested effect sizes that were relatively small. The strongest variant found in one GWAS done in Norway observed rs9949006 on chromosome 18, a variant for the non-coding RNA ENSG00000263745 gene (Zayats et al.). It was noted that SNPs that were located on the non-coding RNA genes were associated with other neurological and psychiatric conditions. There were other several notable contenders such as the gene SLCA9 which has been associated with ADHD previously, as well as the TPH2 gene which has contradictory research circulating around its significance to ADHD (Zayats et al.).

Additionally, another GWAS provided data for childhood ADHD with promising results. The most suggestive region was an area located on chromosome 7, where there were 8 SNPs found, and is found to be closest to the SHFM1 gene. Previous findings have associated this same region with other psychiatric disorders, including Major Depressive Disorder (MDD) and bipolar disorder (Neale et al.). Both of these disorders have often been seen to be comorbid with ADHD as there are overlapping symptoms. The comorbidity of ADHD and bipolar disorder has ranged from 5% to 47% in other studies. While no real studies have been done to solidify this statement, their developments can be influenced by both genetic and environmental factors (Schiweck et al.). Similarly, patients that present with both ADHD and MDD may be overlooked or confused between the two, and can often worsen the symptoms of each other when comorbid. When diagnosing each disorder, it is recommended to screen for other psychiatric disorders as well to further the effectiveness of treatments (Mcintosh et al.).

In the recent largest GWAS study done, 38,691 individuals with ADHD were investigated, where 27 genome-wide significant loci were found to be of importance. Along with those, 76 genes could be contributors to ADHD which play a significant role in premature brain development. The gene SORCS3 was of notable account for ADHD in common and rare variants, which aligns with another study that highlighted the SORCS3 gene as well as FOXP2 and DUSP6 which they claim to be possible biological components of ADHD (Demontis et al.). The SORCS3 gene is involved in the neuropeptide signaling pathway as well as the regulation of long-term synaptic depression (Hampe et al.). However, overall the study helped to shed light on the comorbidity of ADHD with other conditions; a Bivariate Gaussian mixture model estimates that 84-98% of ADHD-influencing variants are also shared with other psychiatric disorders (Demontis et al.).

In 2016, the largest genetic study of anxiety disorders was performed with over 18,000 subjects, and several potentially susceptible loci were identified. There were three major genes at play where SNPs were located, including SLC3A1, PREPL, and CAM KMT. The SLC3A1 gene was found to be mainly involved in the transport of amino acids as well as gene expression (Gaudet et al.). The PREPL gene was found to contribute to the plasma membrane protein transport and the regulation of synaptic vesicle exocytosis (Régál et al.). The CAMKMT gene

codes the protein that is involved in the formation of trimethyl lysine in calmodulin (Pruitt et al.). They suggest that the most likely candidate for anxiety disorders is rs698775 at PREPL, despite the most significant variant residing on the CAMKMT gene (Otowa et al.).

### Heritability and Twin Studies

Heritability studies are focused on discovering how certain traits are passed down between generations as a result of certain variations in the DNA. A study found that ADHD has a higher recurrence rate in families, and in siblings, there was an increased correlation between ADHD in siblings at a rate of 12.7% (Chen et al.).

Other heritability studies concluded that evidence is skewed toward ADHD being of genetic causes rather than environmental factors. One association compared the biological and adoptive parents of children with and without ADHD with parents of hyperactive children presenting with more attention difficulties (Corush and Goodman). Another study addressed the issue of genetics in ADHD utilizing adoptive children in comparison with biological children with both groups presenting with ADHD. The biological parents of children with ADHD had the most family associations with 18% of the parents having ADHD, while the adoptive parents of ADHD probands and biological parents of the control children had similar rates of ADHD at 3 and 6 percent (Corush and Goodman). This means that adoptive relatives of ADHD probands have about the same risk rate of having ADHD as relatives of children who don't have ADHD.

Twin studies evaluate the contribution of genetic and environmental influences on a trait/quality utilizing monozygotic (MZ) twin pairs and dizygotic (DZ) twin pairs. The general consensus among these studies is that there is a large heritability rate of ADHD. In an evaluation of 37 twin studies conducted in relation to ADHD, there was a calculated mean heritability of 74% (Faraone and Larsson).

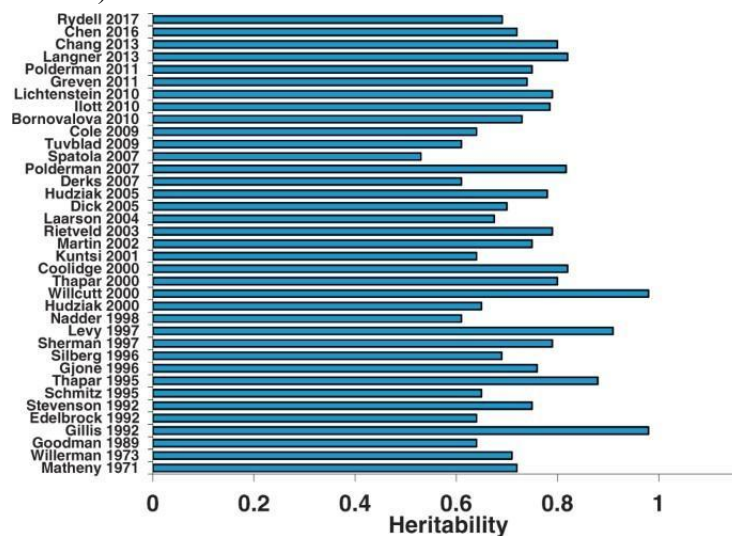


Fig 1: Heritability of ADHD from twin studies of ADHD diagnoses or symptom counts (Faraone and Larsson)

A similar study evaluated multiple familial relationships, such as twins, full and half-siblings, and full and half-cousins. Their hazard rates were calculated, and the monozygotic

twins had an HR rate of 70.45. Conclusions were that the more closely related family members were, the risk of developing the same traits increased, driven by primarily genetic factors and a small number of environmental factors. More evidence supports the discovery that 88% of hyperactive-impulsiveness and 79% of inattentiveness are due to the contribution of genetics in ADHD (Chen et al.). There may be genes that contribute to both of these qualities combined, however, there is a possibility that remains in which there are genes that are trait-specific.

Twin studies performed in regard to GAD have come to similar conclusions that there are genetic contributions to the development of GAD. Analyses suggest the RBFOX1 gene and variants of the gene are involved in anxiety-related disorders and anxiety sensitivity, and other results also suggest that genetic and non-genetic variations are essential to the disorder (Davies et al.). Another investigation of the genetic and environmental influences on GAD found a quarter of the variation in GAD was attributed to genetic factors (Mackintosh et al.).

### **Linkage Studies**

In genetic linkage studies, the genome is investigated to find a segment of DNA that is transmitted in a disorder within families. In general, the findings from these linkage studies are inconclusive or contradictory. In an analysis of the current linkage studies present, there was a slight overlap between the results of different studies, however, none of the findings met genome-wide significance. In general, evidence is severely lacking for loci which means that the likelihood of discovering a gene with a significant effect on ADHD is very low (Faraone and Mick). In a linkage experiment, the linkage scan provided negative results despite other studies indicating a possible correlation. Similarly to the other analyses, their findings rule out the possibility of major genes being involved in the development of ADHD, but the susceptibility loci are not ruled out (Faraone et al.). In an attempt to decipher the results of multiple linkage studies, a genome scan meta-analysis was applied. In one region on chromosome 16, a significant linkage was discovered between 64 Mb and 83 Mb (Zhou et al.). Still, the scarcity of linkage studies and evidence of significant variants point to the unlikelihood of DNA variants having a significant effect.

### **Candidate Genes**

There are numerous studies regarding the studies of genetics ADHD, but the evidence is still severely lacking for GAD and anxiety disorders in general. In an attempt to search for any candidate genes that could be possibly contributing to the development of ADHD and GAD, the lack of studies made the process exponentially more difficult. Despite this, multiple genes were selected and narrowed down to the ones that had the most evidence and were the most promising candidates.

Regarding individual genes for ADHD, a dataset that utilized GWAS was used to single out four different genes, DRD4, ADGRL3, PTCHD1, and COMT, that could be contributing to ADHD either individually or together. The first gene, DRD4 encodes for the dopamine receptors and has been associated with ADHD. The mutations in this gene have been associated with

numerous behavioral phenotypes, including autonomic nervous system dysfunction, attention-deficit/hyperactivity disorder, and the personality trait of novelty-seeking (National Library of Medicine). The gene ADGRL3 is a member of the latrophilin subfamily of G-protein coupled receptors. In a study, investigating the adhesion of G protein-coupled receptor L3 gene variants with the association in ADHD they came to the conclusion that they can infer that ADGRL3 may have a role in the etiology of ADHD (Chatterjee et al.). PTCHD1 is involved in the coding of a membrane protein with a patched domain, and deletions of the gene are seen to have been contributing to intellectual disabilities and autism, which is often comorbid with ADHD (National Library of Medicine). In a study involving mice, the deletion of the PTCHD1 gene shows symptoms of ADHD, sleep disruption, hypotonia, and aggression; although the deletion of the gene is still poorly understood (Wells, et al.). Finally, the COMT gene catalyzes the transfer of a methyl group from S-adenosylmethionine to catecholamines, including the neurotransmitter dopamine (National Library of Medicine). There is a lack of studies regarding the relationship between COMT and ADHD.

For genes involved in GAD, there are more candidate genes compared to ADHD, however severe lack of replicated studies and research, in general, should be considered. Three genes were selected, ACE2, TNF, and DRD2, to investigate further whether they could be in connection with GAD. ACE2 is an angiotensin-converting enzyme, known to be involved in the function of organs having a role in cardiovascular and renal function and fertility. The variants for this gene were found to be interferon-inducible (National Library of Medicine). Though initially, the ACE2 gene seems to have no direct correlation with GAD, a study performed on mice came to the conclusion that suggests that ACE2 may reduce anxiety-like behavior by activating central Mas receptors (Wang et al.).

The TNF gene is also known as the tumor necrosis factor, and the mutations of this gene were found to affect susceptibility to Alzheimer's disease (National Library of Medicine). When investigating the depression and anxiety symptoms at the TNF inhibitor they found that symptoms of depression and anxiety at TNFi initiation are associated with poorer treatment outcomes (Zhao et al.). Finally, the DRD2 gene is found to be associated with anxiety symptoms. Research does implicate that the A1 allele of the dopamine D2 receptor gene plays a part in the development of depression and anxiety. They found associations between the DRD2 A1 allele and early-emerging anxious symptoms (Hayden et al.).

Finally, when cross-referencing genes associated with both GAD and ADHD, four genes were chosen, BDNF, MAOA, SLC6A4, and RBFOX1, to investigate their correlation with the comorbidity of ADHD and GAD. The BDNF gene is also known as the brain-derived neurotrophic factor, and expression of the gene is reduced in Alzheimer's, Parkinson's, and Huntington's disease. It is also suspected that the gene plays a role in the stress response and the biology of mood disorders (National Library of Medicine). The relationship between BDNF and ADHD was studied and a positive correlation was found in a case-control study in the Chinese mainland population (Liu et al.). When investigating the role of Hippocampal BDNF in anxiety vulnerability they found that an impaired BDNF system is a vulnerability factor for anxiety

disorders and affects normal hippocampal function (Janke et al.). The MAOA gene is part of the mitochondrial enzymes that catalyze the oxidative deamination of amines such as dopamine. This gene has been associated with a variety of psychiatric disorders, including antisocial behavior (National Library of Medicine). In an association study of the MAOA gene, there was a correlation found between the transmission of MAOAA promoter polymorphism and the risk of ADHD. Specifically, the short 3.5 repeat allele of MAOA is most likely associated with ADHD and could also be possibly contributing to the gender imbalance in ADHD (Das et al.). The MAOA gene was also studied to see its correlation with GAD, and what was found was that the 041T allele was over-represented in patients suffering from GAD when compared to healthy volunteers (Rujescu et al.). The SLC6A4 gene is a target of psychomotor stimulants and previous results of studies suggest that the gene plays a part in behavior and depression (National Library of Medicine). In GAD, results of a study found that the serotonin transporter gene, SLC6A4 was involved in the etiology of anxiety-related traits (Forstner et al.). In ADHD, similarly, results of a study suggest that the SLC6A4 status may be associated with certain symptoms of ADHD such as behavioral disinhibition, and related brain changes (Park et al.). Finally, the RBFOX1 gene is located in the vicinity of disease-associated variants (National Library of Medicine). The gene has been identified as a risk factor for several psychiatric conditions which is explored further in this study. GWAS on mood and anxiety disorders and neuroticism have extended the spectrum of disorders and behavioral traits involving common variants of RBFOX1. The rare genetic variants of RBFOX1 such as copy number variants and loss-of-function mutations had been related to early-onset neurodevelopment disorders including ADHD. Though the association between anxiety and RBFOX1 is not certain, findings suggest that an increase in expression in anxiety may be a consequence of RBFOX1 genetic variation (Leary et al.).

### **Genetic Editing**

Gene editing is still a relatively new technology with CRISPR headlining the re-emergence. CRISPR is a genetic manipulation tool that directs the Cas9 nuclease to create a site-directed double-strand break using a small RNA molecule as a guide. Modifications to the DNA made with genetic editing are permanent, and numerous ethical problems arise with this technology (Li et al.). Overall, genetic technology has extended the abilities of scientists to illuminate the extent of the genetic contribution to disease by promoting the creation of more accurate cellular and animal models of pathological processes; therefore contributing to learning more about various diseases and discovering molecular mechanisms to be utilized in therapy methods (Haavik). When actually applying gene therapy to the treatment of ADHD, the first step is to start genome-guided therapies starting with the rare ADHD symptoms with highly penetrant risk genes. The identification and treatment of ADHD patients with defined neurometabolic aberrations could further progress in the overall genome-guided personalized treatment (Scheller and Krebsbach).

Gene therapy is the process of transferring genetic material into cells in order to treat a disease. Gene therapy is used as a method to treat people with a single genetic deficiency that has

previously not been affected by protein or pharmacokinetic therapy. About 1,000 clinical trials have been conducted since the introduction of gene therapy in 1990 with positive and recurring results. It has three main methods in order to deliver the gene into the body, *in vivo*, *in vitro*, and *ex vivo*. *In vivo* is the most direct method of insertion, however *in vivo* and *ex vivo* have had more developments when considering patient safety. However, there are promising results from the clinical trials involving the *ex vivo* transduction of cells with integrating retrovirus (Haavik).

## **Conclusion**

Overall, this study conducts an overview of possible genes and contributors to the comorbidity of ADHD and GAD. The genes that were examined in this paper would need further investigation as to whether or not there is a link, as there is a lack of studies that revolve around a correlation between psychiatric disorders, specifically ADHD and GAD. Some of these genes do have studies linking them to one or both of the conditions, but it does not mean a sure link is proven between the two, or that it is the only contributing factor to ADHD and GAD. This information only serves to help further research and development in technology into specialized treatments for both of these disorders. In the future, more studies should attempt to replicate existing studies to add more data as to whether or not these genes are factors.



## Works Cited

- Alberts-Corush, Jody, et al. "Attention and impulsivity characteristics of the biological and adoptive parents of hyperactive and normal control children." *The American Journal of Orthopsychiatry* vol. 56,3 (1986): 413-423. doi:10.1111/j.1939-0025.1986.tb03473.x
- Barrera, Terri L, and Peter J Norton. "Quality of life impairment in generalized anxiety disorder, social phobia, and panic disorder." *Journal of anxiety disorders* vol. 23,8 (2009): 1086-90. doi:10.1016/j.janxdis.2009.07.011
- Chatterjee, Mahasweta, et al. "Adhesion G protein-coupled receptor L3 gene variants: Statistically significant association observed in the male Indo-caucasoid Attention deficit hyperactivity disorder probands." *Molecular Biology Reports* vol. 48,4 (2021): 3213-3222. doi:10.1007/s11033-021-06365-2
- Chen, Qi et al. "Familial aggregation of attention-deficit/hyperactivity disorder." *Journal of Child Psychology and Psychiatry, and allied disciplines* vol. 58,3 (2017): 231-239. doi:10.1111/jcpp.12616
- Chen, Wai, et al. "DSM-IV combined type ADHD shows familial association with sibling trait scores: a sampling strategy for QTL linkage." *American journal of medical genetics. Part B, Neuropsychiatric genetics: the official publication of the International Society of Psychiatric Genetics* vol. 147B,8 (2008): 1450-60. doi:10.1002/ajmg.b.30672
- Das, Manali, et al. "MAOA promoter polymorphism and attention deficit hyperactivity disorder (ADHD) in Indian children." *American journal of medical genetics. Part B, Neuropsychiatric genetics: the official publication of the International Society of Psychiatric Genetics* vol. 141B,6 (2006): 637-42. doi:10.1002/ajmg.b.30385
- Davies, Matthew N et al. "Generalized Anxiety Disorder--A Twin Study of Genetic Architecture, Genome-Wide Association and Differential Gene Expression." *PloS one* vol. 10,8 e0134865. 14 Aug. 2015, doi:10.1371/journal.pone.0134865
- Demontis, Ditte, et al. "Genome-wide analyses of ADHD identify 27 risk loci, refine the genetic architecture and implicate several cognitive domains." *Nature Genetics* vol. 55,2 (2023): 198-208. doi:10.1038/s41588-022-01285-8
- Faraone, Stephen V, and Henrik Larsson. "Genetics of attention deficit hyperactivity disorder." *Molecular psychiatry* vol. 24,4 (2019): 562-575. doi:10.1038/s41380-018-0070-0
- Faraone, Stephen V et al. "Linkage analysis of attention deficit hyperactivity disorder." *American journal of medical genetics. Part B, Neuropsychiatric genetics: the official publication of the International Society of Psychiatric Genetics* vol. 147B,8 (2008): 1387-91. doi:10.1002/ajmg.b.30631
- Faraone, Stephen V, and Eric Mick. "Molecular genetics of attention deficit hyperactivity disorder." *The Psychiatric Clinics of North America* vol. 33,1 (2010): 159-80. doi:10.1016/j.psc.2009.12.004
- Forstner, Andreas J et al. "Further evidence for genetic variation at the serotonin transporter gene SLC6A4 contributing toward anxiety." *Psychiatric Genetics* vol. 27,3 (2017): 96-102. doi:10.1097/YPG.0000000000000171

- Gaudet, Pascale, et al. "Phylogenetic-based propagation of functional annotations within the Gene Ontology consortium." *Briefings in bioinformatics* vol. 12,5 (2011): 449-62. doi:10.1093/bib/bbr042
- Gehricke, Jean-G, et al. "The brain anatomy of attention-deficit/hyperactivity disorder in young adults - a magnetic resonance imaging study." *PloS one* vol. 12,4 e0175433. 13 Apr. 2017, doi:10.1371/journal.pone.0175433
- Gene [Internet]. Bethesda (MD): National Library of Medicine (US), National Center for Biotechnology Information; 2004 – [cited 2023 June 22]. Available from: <https://www.ncbi.nlm.nih.gov/gene/>
- Genome-Wide Association Studies Fact Sheet. National Human Genome Research Institute. (2020, August 17). <https://www.genome.gov/about-genomics/fact-sheets/Genome-Wide-Association-Studies-Fact-Sheet>
- Gottschalk, Michael G, and Katharina Domschke. "Genetics of generalized anxiety disorder and related traits." *Dialogues in clinical neuroscience* vol. 19,2 (2017): 159-168. doi:10.31887/DCNS.2017.19.2/kdomschke
- Haavik, Jan. "Genome Guided Personalized Drug Therapy in Attention Deficit Hyperactivity Disorder." *Frontiers in psychiatry* vol. 13 925442. 27 Jun. 2022, doi:10.3389/fpsy.2022.925442
- Hampe, W et al. "The genes for the human VPS10 domain-containing receptors are large and contain many small exons." *Human genetics* vol. 108,6 (2001): 529-36. doi:10.1007/s004390100504
- Hayden, Elizabeth P. et al. "The dopamine D2 receptor gene and depressive and anxious symptoms in childhood: associations and evidence for gene-environment correlation and gene-environment interaction." *Psychiatric Genetics* vol. 20,6 (2010): 304-10. doi:10.1097/YPG.0b013e32833adccb
- Henning, Eric R et al. "Impairment and quality of life in individuals with generalized anxiety disorder." *Depression and anxiety* vol. 24,5 (2007): 342-9. doi:10.1002/da.20249
- Janke, Kellie L et al. "Investigating the Role of Hippocampal BDNF in Anxiety Vulnerability Using Classical Eyeblink Conditioning." *Frontiers in psychiatry* vol. 6 106. 24 Jul. 2015, doi:10.3389/fpsy.2015.00106
- O'Leary, Aet, et al. "Behavioral and functional evidence revealing the role of RBFox1 variation in multiple psychiatric disorders and traits." *Molecular psychiatry* vol. 27,11 (2022): 4464-4473. doi:10.1038/s41380-022-01722-4
- Liu, De-Yi et al. "The Physiology of BDNF and Its Relationship with ADHD." *Molecular neurobiology* vol. 52,3 (2015): 1467-1476. doi:10.1007/s12035-014-8956-6
- Li, Hongyi, et al. "Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances, and prospects." *Signal transduction and targeted therapy* vol. 5,1 1. 3 Jan. 2020, doi:10.1038/s41392-019-0089-y

- Martin, Elizabeth I et al. "The neurobiology of anxiety disorders: brain imaging, genetics, and psychoneuroendocrinology." *The Psychiatric Clinics of North America* vol. 32,3 (2009): 549-75. doi:10.1016/j.psc.2009.05.004
- Mackintosh, Margaret-Anne, et al. "A twin study of lifetime Generalized Anxiety Disorder (GAD) in older adults: genetic and environmental influences shared by neuroticism and GAD." *Twin research and human genetics: the official journal of the International Society for Twin Studies* vol. 9,1 (2006): 30-7. doi:10.1375/183242706776402902
- McIntosh, Diane, et al. "Adult ADHD and comorbid depression: A consensus-derived diagnostic algorithm for ADHD." *Neuropsychiatric disease and treatment* vol. 5 (2009): 137-50. doi:10.2147/ndt.s4720
- Neale, Benjamin M et al. "Meta-analysis of genome-wide association studies of attention-deficit/hyperactivity disorder." *Journal of the American Academy of Child and Adolescent Psychiatry* vol. 49,9 (2010): 884-97. doi:10.1016/j.jaac.2010.06.008
- Otowa, T. et al. "Meta-analysis of genome-wide association studies of anxiety disorders." *Molecular psychiatry* vol. 21,10 (2016): 1391-9. doi:10.1038/mp.2015.197
- Park, S et al. "Associations between serotonin transporter gene (SLC6A4) methylation and clinical characteristics and cortical thickness in children with ADHD." *Psychological medicine* vol. 45,14 (2015): 3009-17. doi:10.1017/S003329171500094X
- Pruitt, Kim D et al. "NCBI Reference Sequences (RefSeq): current status, new features, and genome annotation policy." *Nucleic acids research* vol. 40, Database issue (2012): D130-5. doi:10.1093/nar/gkr1079
- Régal, Luc et al. "PREPL deficiency with or without cystinuria causes a novel myasthenic syndrome." *Neurology* vol. 82,14 (2014): 1254-60. doi:10.1212/WNL.0000000000000295
- Scheller, E L, and P H Krebsbach. "Gene therapy: design and prospects for craniofacial regeneration." *Journal of Dental Research* vol. 88,7 (2009): 585-96. doi:10.1177/0022034509337480
- Schiweck, Carmen, et al. "Comorbidity of ADHD and adult bipolar disorder: A systematic review and meta-analysis." *Neuroscience and Biobehavioral Reviews* vol. 124 (2021): 100-123. doi:10.1016/j.neubiorev.2021.01.017
- Schoenfelder, Erin N, and Scott H Kollins. "Topical Review: ADHD and Health-Risk Behaviors: Toward Prevention and Health Promotion." *Journal of Pediatric Psychology* vol. 41,7 (2016): 735-40. doi:10.1093/jpepsy/jsv162
- Sprich, S et al. "Adoptive and biological families of children and adolescents with ADHD." *Journal of the American Academy of Child and Adolescent Psychiatry* vol. 39,11 (2000): 1432-7. doi:10.1097/00004583-200011000-00018
- Söderquist, Fanny, et al. "A cross-sectional study of gastrointestinal symptoms, depressive symptoms, and trait anxiety in young adults." *BMC Psychiatry* vol. 20,1 535. 11 Nov. 2020, doi:10.1186/s12888-020-02940-2

- Tadic, A. et al. "Association of an MAOA gene variant with generalized anxiety disorder, but not with panic disorder or major depression." *American journal of medical genetics. Part B, Neuropsychiatric genetics: the official publication of the International Society of Psychiatric Genetics* vol. 117B,1 (2003): 1-6. doi:10.1002/ajmg.b.10013
- Wang, Lei, et al. "Increasing brain angiotensin-converting enzyme 2 activity decreases anxiety-like behavior in male mice by activating central Mas receptors." *Neuropharmacology* vol. 105 (2016): 114-123. doi:10.1016/j.neuropharm.2015.12.026
- Wells, Michael F et al. "Thalamic reticular impairment underlies attention deficit in Ptchd1(Y/-) mice." *Nature* vol. 532,7597 (2016): 58-63. doi:10.1038/nature17427
- Wilens, Timothy E, and Thomas J Spencer. "Understanding attention-deficit/hyperactivity disorder from childhood to adulthood." *Postgraduate medicine* vol. 122,5 (2010): 97-109. doi:10.3810/pgm.2010.09.2206
- Zayats, Tetyana et al. "Genome-wide analysis of attention deficit hyperactivity disorder in Norway." *PloS one* vol. 10,4 e0122501. 13 Apr. 2015, doi:10.1371/journal.pone.0122501
- Zhao, Sizheng Steven et al. "Depression and anxiety symptoms at TNF inhibitor initiation are associated with impaired treatment response in axial spondyloarthritis." *Rheumatology (Oxford, England)* vol. 60,12 (2021): 5734-5742. doi:10.1093/rheumatology/keab242
- Zhou, Kaixin, et al. "Meta-analysis of genome-wide linkage scans of attention deficit hyperactivity disorder." *American journal of medical genetics. Part B, Neuropsychiatric genetics: the official publication of the International Society of Psychiatric Genetics* vol. 147B,8 (2008): 1392-8. doi:10.1002/ajmg.b.30878

# Predicting the Progression of Alzheimer's Disease Using Neural Networks By Nitya Reddy

## Abstract

Alzheimer's disease is a neurodegenerative disorder that affects millions of people worldwide. Early detection and accurate prediction of disease progression are crucial for better patient management and treatment planning. This research paper explores the utilization of neural networks and hyperparameter optimization to predict the progression and likelihood of Alzheimer's disease based on demographic and clinical features. The study employs preprocessing techniques, including data cleansing, feature scaling, and label encoding, to prepare the dataset for modeling. A neural network architecture is constructed using the TensorFlow and Keras frameworks, with varying activation functions and optimizers. Hyperparameter optimization is performed using GridSearchCV to identify the best combination of hyperparameters for optimal model performance. The results demonstrate the effectiveness of the proposed approach in predicting Alzheimer's disease progression.

## Introduction

Alzheimer's disease is a progressive neurological disorder characterized by cognitive decline and memory impairment. Early diagnosis and accurate prediction of disease progression are crucial for effective intervention and care planning. Machine learning techniques, particularly neural networks, have shown promise in predicting disease outcomes based on clinical and demographic information in research and new discoveries. This research aims to develop a predictive model for Alzheimer's disease progression using neural networks and hyperparameter optimization.

## Materials and Methods–Dataset:

The dataset used in this study consists of demographic and clinical data collected from individuals with varying cognitive statuses. The dataset includes features such as age, gender, education level, Mini-Mental State Examination (MMSE) score, and others. The target variable, denoted as 'Group,' categorizes individuals into different classes related to their cognitive status. The dataset was preprocessed to handle missing (null) values, encode categorical variables, and standardize features. The key features below highlight different risk factors that predict the onset of Alzheimer's in my research:

- Age:
  - Age is a crucial factor linked to Alzheimer's disease development.
  - The risk of Alzheimer's tends to increase with age.
  - Cognitive decline and neurological changes are often associated with aging.
- Gender (M/F):
  - Gender is a potential influencer of Alzheimer's risk.
  - Some studies suggest a higher prevalence among women.

- Analyzing gender differences can provide insights into susceptibility.
- Education Level:
  - Educational background might impact cognitive reserve which is the brain's defense against damage.
  - Higher education could enhance resilience against Alzheimer's pathology.
  - Education's role in cognitive reserve might affect disease progression.
- Mini-Mental State Examination (MMSE) Score:
  - MMSE gauges cognitive function and helps diagnose cognitive impairment and Alzheimer's.
  - Lower MMSE scores might indicate disease advancement.
  - It offers quantifiable insight into cognitive abilities for prediction.
- Estimated Total Intracranial Volume (eTIV):
  - eTIV reflects brain size, potentially linked to cognitive reserve.
  - Changes in brain volume might indicate neurodegenerative processes.
  - Brain size variations might contribute to Alzheimer's likelihood.
- Normalized Whole Brain Volume (nWBV):
  - nWBV quantifies brain atrophy, a hallmark of Alzheimer's.
  - Reduced nWBV could signal disease progression.
  - Brain atrophy is a key indicator of neurodegenerative changes.
- Atlas Scaling Factor (ASF):
  - ASF normalizes brain volumes, ensuring consistency across measurements.
  - Standardization is crucial for precise analysis.
  - ASF enhances accuracy in measuring brain volume.
- Clinical Dementia Rating (CDR):
  - CDR assesses dementia severity.
  - Higher CDR scores indicate advanced cognitive impairment.
  - CDR quantifies disease seriousness effectively.
- Estimated Years to Onset (eYO):
  - eYO predicts years until dementia onset.
  - A critical variable for predicting disease progression.
  - eYO aids in anticipating Alzheimer's timeline.

These independent factors provide valuable insights into Alzheimer's disease. As people get older, the risk of getting Alzheimer's disease also becomes more common. Women also have a greater probability of developing the disease. The level of education affects the brain's ability to defend against damage. Tests like the MMSE score help us understand how the disease is progressing. Brain size measurements, such as eTIV and nWBV, show us changes in the brain's structure that could relate to the disease. In addition, ASF and CDR ensure the methods are accurate and give us a clear understanding of the disease's severity. Lastly, the eYO helps us predict when the disease might appear. We apply these factors as inputs into our model to

develop an overview of the factors that could impact Alzheimer's disease. By analyzing different aspects such as age, gender, education, cognitive tests, brain measurements, and predictive tools, we can better understand how the disease develops and find ways to manage it more effectively.

## **Data Preprocessing**

Before training the neural network, the dataset underwent preprocessing steps. Missing values were imputed with the mean of the respective columns. Categorical variables such as gender were encoded into numerical values using label encoding. The 'Group' column was transformed into numerical labels to facilitate classification. An example of this would be using '0' for 'Nondemented Individuals' and using '1' for 'Demented Individuals,' to correctly differentiate between those two values which would be the cross entropy loss function. The neural network architecture was designed to predict the cognitive status of individuals based on the provided features. The input layer consists of 11 nodes, corresponding to the selected features. Two hidden layers follow, each containing 128 nodes, utilizing the ReLU (Rectified Linear Unit) activation function to introduce non-linearity. The output layer, with 4 nodes, matches the number of unique classes in the 'Group' column. The model was compiled with the 'sparse\_categorical\_crossentropy' loss function and 'accuracy' as the evaluation metric. I chose 128 nodes in two hidden layers to be able to capture complex patterns while avoiding overfitting. To fine-tune the model architecture and achieve optimal predictive performance, I opted for 128 nodes in the hidden layers after considering the complexity of the data and the potential representation power of the neural network. While it's not a predefined or universal value, I found that 128 nodes strike a balance between capturing intricate patterns in the data and avoiding overfitting.

In addition, two hidden layers allow for a middle ground between capturing essential patterns and preventing excessive complexity. The combination of two hidden layers with ReLU activation functions helps in capturing both linear and non-linear relationships present in the data. To ensure that the chosen number of nodes and layers were suitable for the task, I employed a validation dataset during hyperparameter optimization. Hyperparameter optimization was carried out using GridSearchCV, exploring various combinations of activation functions and optimizers. By evaluating the model's performance on the validation dataset, I selected the architecture that exhibited the best balance between accuracy and prevention of overfitting. The neural network model was trained using the preprocessed dataset. A train-test split was performed, allocating 90% of the data for training and 10% for testing using scikit. The training data was further divided into batches to improve optimization efficiency. Hyperparameter tuning was conducted using GridSearchCV, exploring different combinations of activation functions ('ReLU' and 'sigmoid') and optimizers ('adam', 'sgd', and 'RMSprop'), which had the most efficient results.

The performance of the trained neural network was evaluated using the test dataset. The accuracy metric was used to assess the model's ability to classify cognitive status correctly. The

best combination of hyperparameters that yielded the highest accuracy was identified from the hyperparameter tuning process.

The neural network was implemented using the TensorFlow and Keras libraries in Python. The training process involved iterating over the dataset for a certain number of epochs and updating the model's weights using backpropagation. The best-performing model was selected based on its accuracy on the test dataset. The equation for backpropagation can be described as follows:

$$\frac{\delta E(X, \theta)}{\delta w_{ij}^k} = \frac{1}{N} \sum_{d=1}^N \frac{\delta}{\delta w_{ij}^k} \left( \frac{1}{2} (\hat{y}_d - y_d)^2 \right) = \frac{1}{N} \sum_{d=1}^N \frac{\delta E_d}{\delta w_{ij}^k}$$

The Alzheimer's dataset used in this study was sourced from the provided Excel file, found in Kaggle. The dataset includes various features related to patients' demographics and clinical attributes. The following preprocessing steps were applied to ensure the quality of the data:

**Handling Missing Values:** Null values were identified and imputed with the mean of their respective columns.

**Irrelevant Feature Removal:** Columns such as 'MRI ID,' 'Subject ID,' and 'Hand' were considered irrelevant and dropped from the dataset. 'Hand' was dropped since all the values were the same so it would not change the output.

**Categorical Encoding:** Categorical variables, such as 'Group' and 'M/F,' were encoded into numerical values using label encoding.

**Feature Scaling:** The features were standardized using the StandardScaler to ensure that all input features were on the same scale.

The 12 data columns involved are also important in differentiating who is at risk of getting Alzheimer's and who is not. The first one is age and it is a crucial demographic factor associated with Alzheimer's disease. As individuals age, the risk of developing Alzheimer's increases. Neurological changes and decreased cognitive function are often correlated with aging. Gender (M/F) might also play a role in Alzheimer's risk since some studies suggest that women might have a higher prevalence of Alzheimer's.

Educational background can also influence cognitive reserve, which is the brain's ability to resist damage. Higher education might provide cognitive resilience against Alzheimer's pathology. Socioeconomic status and factors can impact access to healthcare, lifestyle choices, and stress levels, all of which may influence Alzheimer's risk.

The MMSE Score (Mini-Mental State Examination) assesses cognitive function and is commonly used in diagnosing cognitive impairment and Alzheimer's. Lower MMSE scores could indicate disease progression. eTIV (Estimated Total Intracranial Volume): reflects brain



size and might be related to cognitive reserve. Changes in brain volume could be indicative of neurodegenerative processes. nWBV (Normalized Whole Brain Volume): measures brain atrophy, which is a characteristic of Alzheimer's disease. Decreased nWBV might indicate disease progression. ASF (Atlas Scaling Factor): used to normalize brain volumes. It could help ensure consistency in brain volume measurements across subjects. CDR (Clinical Dementia Rating): assesses the severity of dementia. Higher CDR scores indicate more advanced cognitive impairment. eYO (Estimated Years to Onset): estimates the number of years until the onset of dementia. It's a critical variable for predicting disease progression.

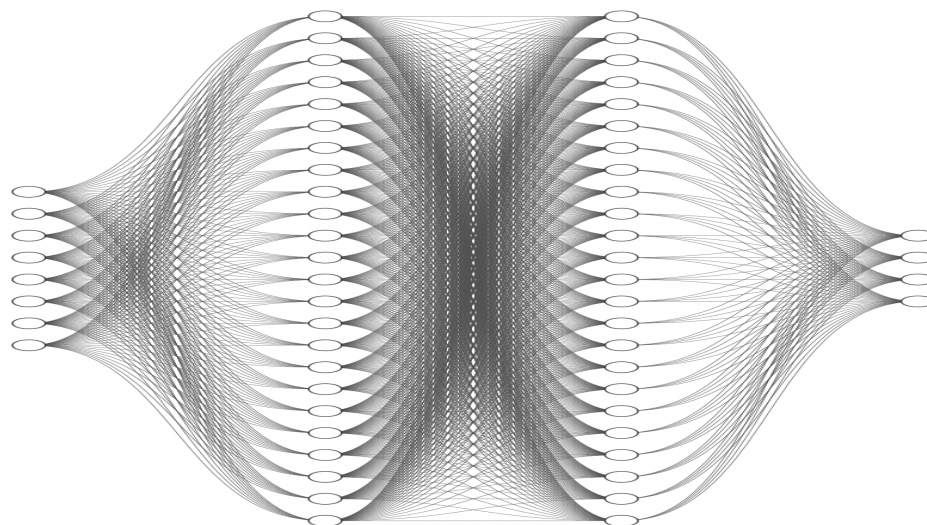
The group is the target variable indicating the group to which the subject belongs to: ex. 'Demented' or 'Nondemented'. The column hand was also dropped since all the values in the column were 'Right,' so it would not be necessary to include, since there is no differentiation in that column.

A feedforward neural network architecture was designed using the Keras library from TensorFlow. The model was compiled with the 'sparse\_categorical\_crossentropy' loss function and 'accuracy' as the evaluation metric. The model architecture consists of three dense layers:

1. Input Layer: 12 nodes, activation function based on user-defined parameter
2. Hidden Layers: 2 layers, 128 nodes, activation function based on user-defined parameter
3. Output Layer: 4 nodes, sigmoid activation for multiclass classification

Hyperparameter optimization is crucial for achieving the best performance of the neural network model. To find the optimal combination of hyperparameters, GridSearchCV was employed. Both Activation functions: 'relu,' 'sigmoid,' and Optimizers: 'adam,' 'sgd,' 'RMSprop,' were tuned. In this research, I found the best combination of hyperparameters was determined based on cross-validated performance using a 3-fold cross-validation strategy.

Figure of the Neural Network: 12, 128, 128, 4



In my neural network, I opted to use ReLU (Rectified Linear Unit) activation functions to model out the non-linearity of the dataset. Given we're working with many layers, ReLU helps mitigate the vanishing gradient problem, which can hinder the model's learning progress. ReLU's nonlinearity is essential for capturing intricate relationships within my data that linear functions might overlook. What's particularly intriguing is ReLU's ability to generate sparse activations, which can prevent overfitting by honing in on essential features while disregarding unnecessary noise.



The preprocessed dataset was split into training and testing sets using a 90-10 ratio. The training data was further converted to 'float32' to match the neural network's input requirements. The model was trained on the training data using the optimal hyperparameters obtained from the hyperparameter optimization step. The performance of the model was evaluated on the testing set.

## Results

The results of the study highlight the importance of hyperparameter optimization in achieving better model performance. The following outcomes were observed:

**The best combination of hyperparameters:** The optimal combination of activation function and optimizer was determined to be 'relu' and 'adam,' respectively. The hyperparameters in this case would be the learning rate, batch sizes, and epochs.

**Model Performance:** The model achieved an accuracy of 88% on the testing set, demonstrating its effectiveness in predicting Alzheimer's disease progression by using multiple factors.

Accuracy is measured using the 'accuracy' metric, which is a common evaluation metric for classification tasks like the one presented here. Accuracy measures the proportion of correctly classified instances in the total number of instances in the test set. Since my model is performing classification by predicting the 'Group' variable, which represents different groups of many subjects, accuracy is the best metric to use to evaluate how well the model predicts the correct group labels.

A comprehensive comparative analysis is undertaken, comparing the performance of the non-imaging data-driven approach with conventional baseline models such as logistic regression

and decision trees. The results resoundingly exhibit competitive performance, attesting to the efficacy and viability of non-imaging data in predicting Alzheimer's disease risk. The default number of epochs is often set to 1 (usually epochs is greater than one and the number of epochs is determined by the underfitting or overfitting of the model given early stopping) and the default batch size is set to 32. This means that the training dataset is divided into batches of 32 samples, and the model's weights are updated after each batch.

## Discussion

The research demonstrates that a well-designed neural network, combined with hyperparameter optimization, can provide accurate predictions of Alzheimer's disease progression based on demographic and clinical features. The achieved accuracy underscores the potential utility of this approach in clinical settings.

**Training Set:** The training set comprises a majority of the data (approximately 90% of the entire dataset). It is used to train the neural network's parameters, which are the weights and biases of the network's layers. During training, the model iteratively adjusts these parameters to minimize the loss function, aiming to make accurate predictions on the training data. The training set is used in conjunction with backpropagation to update the weights of the network's layers based on the computed gradients.

**Test Set:** The test set accounts for approximately 10% of the dataset. This subset is used to assess the final performance of the trained neural network. After the model has been trained, it is evaluated on the test set to measure its ability to generalize to new, unseen data. The accuracy and other relevant metrics computed on the test set provide insights into the model's performance and its potential to make accurate predictions on new instances.

The division between training and test sets is accomplished using the `train_test_split` function, where the `test_size` parameter is set to 0.1 (or 10% of the data) in the code. This split is used to separate the data into training and testing subsets. A form of validation is implicitly performed during the hyperparameter optimization process within the `GridSearchCV`. Cross-validation, likely with a value of 3 (as specified by `cv=3`), is employed to assess the model's performance on different folds of the training data. This helps in selecting the best combination of hyperparameters, which indirectly validates the model's performance on unseen data. The training set is used for parameter learning, the test set is for final evaluation, and cross-validation during hyperparameter tuning mimics validation.

The application of non-imaging data in Alzheimer's disease risk prediction cascades into pragmatic implications for early intervention and personalized patient care. The ensuing dialogue delves into the prospective clinical applications and paves a trajectory for future research endeavors.

## Conclusion

This research represents a significant advancement in predicting the risk of Alzheimer's disease based on PyTorch. By combining information from both the "converted" and "demented" groups, I've addressed the challenge of unequal sample sizes in these groups. This approach has yielded impressive results in predicting individuals who might be at risk of Alzheimer's disease. Additionally, I've found that using data-driven methods focused on information other than images, such as demographic and clinical details, could be immensely valuable for early disease detection and delivering improved patient care. I have also enhanced the model's performance by employing a specialized formula known as a "cross-entropy loss function." This formula assists the model in learning how to make predictions that are either very close to 0 or 1. This refinement aids in making more accurate predictions, particularly when dealing with cases that are difficult to distinguish.

To summarize, my research is launched by PyTorch-powered neural networks, inventive strategies for handling different groups, and specific formulas to redefine Alzheimer's disease risk prediction. These innovations hold substantial promise for advancing early detection and providing more personalized patient care.

The areas of future research may include working with other supplementary datasets that encompass genetic insights and lifestyle attributes to further elevate the predictive ability of the model. Moreover, the effort to enhance the model's predictive ability across diverse demographic groups points to a promising direction for its integration and practical use in clinical settings. The aim of this study is to determine the primary factors that contribute to Alzheimer's disease. A meticulous analysis has illuminated the pivotal role played by these specific twelve factors in the intricate tapestry of Alzheimer's onset. The model stands to also effectively determine an individual's susceptibility to dementia. With knowledge of these predictive capacities, proactive healthcare and personalized interventions can be formulated, thereby enhancing the effectiveness of disease management approaches and reinforcing interventions for individuals at potential risk.

## Works Cited

Kaggle dataset link: <https://www.kaggle.com/datasets/jboysen/mri-and-alzheimers>

Neural Network figure: <https://alexlenail.me/NN-SVG/index.html>

Equation for backpropagation:

<https://brilliant.org/wiki/backpropagation/#:~:text=Plugging%20this%20into%20the%20above,1%20%CE%B4%20%20k%20%2B%201%20>.

Backpropagation. *Brilliant.org*. Retrieved 23:04, September 7, 2023, from

<https://brilliant.org/wiki/backpropagation/>

Daniel S. Marcus, Tracy H. Wang, Jamie Parker, John G. Csernansky, John C. Morris, Randy L. Buckner; Open Access Series of Imaging Studies (OASIS): Cross-sectional MRI Data in Young, Middle Aged, Nondemented, and Demented Older Adults. *J Cogn Neurosci* 2007; 19 (9): 1498–1507. doi: <https://doi.org/10.1162/jocn.2007.19.9.1498>

## Thresholds of Transformation Exploring Dorothea Tanning's Femme Enfant By Myra Prasad

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### Abstract

This research paper explores the artworks of Dorothea Tanning to understand how she employs the concept of the “femme enfant” along with the symbolism of doors as a means of challenging and subverting patriarchal norms. Through an intertextual analysis of Tanning’s artworks, I examined her paintings, poems, and interviews to gain insight into Tanning’s view of patriarchal inequality and her use of motifs to upturn conventional tropes of gender. The opening of the door goes hand in hand with the degree of patriarchal control over the figures, and the femme enfants act as symbols of resistance. They invite viewers to question societal norms, the construction of gender, and the roles individuals are forced to play in society. This research not only deepens our understanding of Dorothea Tanning’s artistry but also sheds light on broader conversations about gender representations in art. It highlights the use of visual art as a platform for the subversion of oppressive notions and as an attempt for agency.

**Keywords:** Dorothea Tanning, Femme-Enfant, Intersectional Art Criticism, Surrealism

### Introduction

The aim of this research is to explore how the American surrealist artist Dorothea Tanning uses the image of the “femme enfants” to critique gendered roles and moral codes for women. Dorothea Tanning’s appropriation of the surrealist female nude is referred to as the Femme-enfant, which is a combination of the French words for ‘female’, *femme*, and ‘infant’, *enfant*. The femme enfants are one of Tanning’s methods of representing and exploring questions on gender and social norms. These figures are hybrids, with childlike and adult features, some feminine and masculine traits, and also linked to nature. The bodies may have the proportions or curves that are associated with adult women, while they still possess features and a sense of delicacy that is reminiscent of childhood. The images Tanning creates are a fusion of adult maturity and childhood wonder or inexperience, and they embody qualities and experiences that cannot be easily confined to a particular age group (Chadwick and Latimer 2019).

Artists have historically played a crucial role in challenging and altering gendered roles and conceptions of norms for women, which frequently prescribe specific characteristics like clothes, occupations, and gendered behaviours, thereby limiting the freedoms of women and gender non-conforming people. A notable 20th-century artist named Dorothea Tanning set out on a transformative artistic path, employing the idea of femme enfants to challenge and subvert some of these cultural norms. This study explores Tanning's artistic and anti-sexist strategies, with particular

emphasis on her use of the figure of the femme enfant, through a careful inter-textual scrutinisation of her paintings, sculptures, and writings.

Dorothea Tanning is an American-born, self-taught painter and sculptor who engaged in surrealist art and writing. She is Swedish-American and was born in the town of Galesburg, Illinois in 1910. She spent her childhood in this isolated town where “nothing happened but the wallpaper” (Tanning, 1977, 34). In that context of a setting, it was easy for Tanning to fuel her imagination creating stories featuring fairies, monsters, and strange creatures that did not exist in reality (Gruen, 1991, 262). She liked to draw at the young age of seven and would frequent the Galesburg library during her adolescence. She enrolled in Knox College for two years before leaving to attend the Art Institute in Chicago. Paula Lumbard discusses Tanning’s life in her essay *Dorothea Tanning: On a Threshold to a Darker Place* (1981) and mentions that she left the institute after two weeks, claiming that no one could teach her to be an artist. She educated herself for the next two years, visiting art museums in New York City, Chicago, and San Francisco. In 1937, she discovered other artists with a similar vision at the New York Museum of Modern Art’s “Fantastic Art- Dada and Surrealism” exhibition.

This introduction to surrealism was a crucial moment in Tanning's artistic journey, and her artwork slowly grew to take on several key elements of this genre. Surrealism as an art form emerged in Paris during a time of great uncertainty in the 20th century. In his *First Manifesto of Surrealism* (1924), Andre Breton described the term ‘surrealism’ by quoting dictionaries and encyclopedias: as “Pure psychic automatism by which it is intended to express, either verbally or in writing, or otherwise, the true function of thought. Thought dictated in the absence of all control exerted by reason, and outside aesthetic or moral preoccupations” (Breton, 1924, 87–88). The critical flavor of this surrealist "movement" can perhaps also be traced to its origins within Europe after the first World War. Thus, it has been argued that the artists who came together in Paris in the early 1920s under this banner term did not merely have a shared aesthetic program but also shared political beliefs, in that many of them professed a “deep mistrust of materialistic, bourgeois society, which they believe[d] was responsible for the First World War and its terrible aftermath” (Klingsöhr-Leroy, 2004, 6–7). Surrealism hence emerged as a movement that embraced art and literature and strayed from convention. Well-known artists in this field include- Max Ernst, Andre Breton, and Rene Magritte.

Jordan Reznick (2022, 1) mentions how surrealist art materialized in this context, to explore and push the boundaries between the known, unknown, and the unconscious. Artists were able to reconfigure relationships between the body, mind, nature, and elements in the environment. The ideas of Sigmund Freud were central to the movement, and Breton adopted them to suit his own purpose. There was an emphasis on the rediscovery of the power of dreams and imagination and a new intellectual tendency that would focus on the psyche and free artists from the control of reason (Klingsöhr-Leroy, 2004, 7). This artwork visualized a large range of images, which were deviations from the contemporary norms of gender, age, and human life. Figures in surrealist works represented meanings and symbols through various forms like hybrids of men and women, humans and nature, or even humans and objects. The art usually features bold colors, optical illusions, and even

disturbing imagery. Salvador Dali's *The Persistence of Memory* (1931) is arguably the most famous surrealist artwork, which symbolizes the relativity of space and time with the symbolism of three melting clocks draped over a barren landscape. Dorothea Tanning's work also incorporates the concept of surrealism, however has a non-traditional approach. Her artworks usually depict settings like corridors and rooms, unlike most surrealist art that stretches across barren landscapes. Like much of other surrealist work, Dorothea Tanning's work has roots in Dadaism and reflects similar psychosexual imagery that I aim to analyse later in the paper.<sup>18</sup>

Given this strong interrelation between the origin of surrealism and the subversion of social and artistic norms, surrealist art soon became the subject of intense feminist and scholarly debate. Feminist scholarship on surrealism first emerged in the early 1920s in the United States and France but was further energised by the second wave of the feminist movement that reached its heyday in the mid-1900s. One crucial text herein is *Surrealism et Sexualite* (2010) which was a detailed investigation of Surrealism's representation of women provided by Xaviere Gauthier. Gauthier uses Simone de Beauvoir's work in *The Second Sex* (1949) and critiques the patriarchal construction of 'Woman' in Western societies. Gauthier's analysis includes a look into most male surrealist images of women- the femme-enfant, femme fatale, ethereal being, or the flower-woman. It concludes that "the Surrealist woman is a male construct" (1971, 190) and most representations in surrealist art, in fact, provide only a phallogocentric view of women, despite the subversive origins of the genre.

Gloria Orenstein's essay *Women of Surrealism* (1973) was the first known 'gynocritical' attempt to make female surrealist artists visible. Gynocriticism is a critique mechanism that analyses the work of artists through a female-centric approach. Orsenstein makes an effort to make visible female artists like Leonora Carrington, Joyce Mansour, Remedios Varo, Leonor Fini, and Dorothea Tanning. Interestingly, most female surrealist artists rejected these notions of being a 'female' artist or writing or creating women's art or poetry. Instead, they tried to assert that creativity had no sex or gender. Dorothea Tanning stated, "Women artists. There is no such thing — or person. It's just as much a contradiction in terms as 'man artist' or 'elephant artist'". (McCormick, Tanning, 1990, 39–40) Despite her dismissal of the term "woman", this quote does seem to be a feminist statement, where Tanning criticises the need to differentiate or mention gender while talking about someone's occupation.

Nevertheless, as highlighted by Orsenstein, Tanning was a prominent feminist figure within surrealism, whose writing and artworks engaged with questions of gender and femininity against a backdrop of patriarchal inequalities both within the art world, and beyond, in the broader society in which she lived. Through the figure of the femme enfant, Tanning explores the maturation of children into adults and the gender norms that await them as they step into adulthood. In *Children's Games* (1942), for example, two childlike figures are seen tearing away wallpaper to reveal underlying sexual imagery. Tanning's art is also heavily symbolic, with various recurring motifs across her paintings and her writings. Doors and windows represent thresholds and change, whilst mirrors encourage reflection and prompt thought about one's identity and self-perception (Coxon,

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<sup>18</sup> Dadaism is the name of of an art movement that emerged during the World War 1 that rejected rationality and reason.



2018). As we will see, the line between reality and the world of dreams and nightmares is frequently seen to be blended in her works through hybrid creatures like the ‘femme enfant’.

This paper will proceed as follows. First, I will explore the hybrid character of the femme enfant as it is depicted in the works of surrealist writers and artists. Here I will examine how Tanning's depictions of the femme enfant incorporate surrealist aesthetics, whilst also reappropriating these elements through a feminist lens. Secondly, I will examine the various symbols that Tanning employs in her expositions of patriarchal inequality, which are the femme enfant and doors. Finally, I will argue that the hybrid figure of the femme enfant and the symbolism of doors represent the desirability of living outside gender norms, thereby overturning conventional tropes of gender as natural.

### **What is the ‘Femme-enfant’?**

The female nude is a common motif in Western contemporary art. On the one hand, nude female and femme figures have been used liberally by artists to break the confines of realism and morality. On the other hand, several critics have pointed out that, given the dominance of white heterosexual men in artistic spaces, female nudes are frequently depicted in objectifying and phallogocentric ways, that minimise their subjectivity and agency. Andre Breton, a prominent figure in the surrealist scene admired the idea of the femme enfant- the woman-child. According to Breton, the woman-child was uncorrupted by logic or abstract thought and hence stated “the time should have come to declare oneself in art unequivocally against man and for woman” (Breton, 1944, 62). The femme-enfant was looked at as an example of purity, innocence, and naivete that connected her more to the realm of unconsciousness and dreams, rather than reality. Breton’s admiration and ideas of women seem to be misplaced and create an impact opposite to the intent. Breton in an attempt to empower the female body incorporates it into his art, however, the impact of his action is not as desired. The subject of the painting, in this case the woman, is misunderstood, hence misrepresented in the artwork. Her body might be looked at as a tool for oppression or something to be sexualised rather than a liberatory figure.

Certain influential surrealist painters and writers have strongly opposed these objectifying depictions of women within art, and have spoken positively regarding increased rights and freedoms for women. However, while this criticism of female nudity in art is perhaps intended to aid liberatory programs for women, in practice, it also has a chilling effect on feminist reinterpretations of the female form, such as Tanning's visions of the femme enfant. Critics who dismiss all artwork with female nudity as objectifying, fail to understand the nuanced intentions of artists like Leonara Carrington and Dorothea Tanning. Such artists, who aim to engage in feminist reinterpretations of the female body often use the femme enfant as a means to attain liberation or explore the themes of autonomy, empowerment, and identity. Another rebellious and empowering approach to this figure is seen in the work of Frida Kahlo. Kahlo uses self-portraits to defy gender stereotypes and express agency. In her painting *Two Nudes in a Forest* (1939) she depicts two figures at the edge of a forest. One is sitting, while the other lays down, both figures are naked and have their breasts exposed.

They portray liberation from the conventional ways a woman is supposed to dress or behave. The painting challenges restrictive clothing and shows freedom of her sexuality.

In light of this general discussion on representations of women as femme-enfants in surrealist artworks, we can now move on to focus on Tanning's reinterpretations in particular. Her work challenges the idea that there is a single, universal concept of woman, and suggests the possibility of alternative value systems that protect gender freedoms. Tanning used the term 'femme enfant' to refer to her depictions of 'child-women', that is, figures that have a fusion of features, both adult and childlike. These figures were sometimes shown as naive and innocent, and at other times experienced and wise. These figures are often depicted in hazy and surreal environments, such as *Far From* (1964) and *Woman Artist, Nude, Standing* (1987) which show colourful, unblended strokes in both, the background and on the relatively free-formed subject. These colourful and unblended backgrounds have the effect of disorienting reality and providing a dreamlike setting. As we will see in our analysis of the famous painting *Door 84* (1984), the fluid strokes can represent freedom of creativity, but can also evoke psychological tension or conflict.

One canonical depiction of the femme enfant in surrealist works is Lewis Carol's Alice, the young female protagonist in the literary classics *Alice in Wonderland* (1865) and *Through the Looking Glass* (1866). In *Surrealism's Curiosity: Lewis Carroll and the Femme-Enfant* (2011) Catriona McAra argues that Tanning's femme enfant has several features that can be considered appropriations from the literary character of "Alice". McAra points out that the 'little Alice figure' is a motif that is frequently found in the artworks of first and second-generation surrealists. Another reference is made by John Russell as he points out that 'a post-Freudian "Alice" is enacted before us in [Tanning's] *Eine Kleine Nachtmusik*' (1943). Alyce Mahon also makes a reference to Alice while discussing the aforementioned painting *Children's Games* (1942).

Lewis Carroll's Alice is a Caucasian, blonde-haired girl, Much like the figures seen in Tanning's art. This is one of the main reasons why Tanning's depictions are called appropriations of Alice. Furthermore, just as Alice enters a dark world of fantasy and imagination, so do Tanning's femme enfants. *Eine Kleine Nachtmusik* is reminiscent of a scene in *Through the Looking Glass* where Alice encounters talking flowers (McAra, 2011, 9). In Tanning's rendition, the sunflower seems to have been one from 'Wonderland' that has entered the real world to become overgrown and intimidating. The flower has "brought erotic nocturnal knowledge" according to McAra who refers to the flower's symbolic and archaic meaning of defloration.

The image of the femme enfant plays several roles in the works of Tanning— a genderless figure, a pre-pubescent child, a young woman, and a mother. Each of these representations are incorporated into art in an attempt to empower the female body. The femme enfant is used by Tanning to achieve liberation from patriarchal forces and socialisation.

### **The Door to Patriarchy**

In this section, I will discuss the work of Tanning and her use of symbolism through an intertextual approach. I will elaborate on her understanding of sexism and gender oppression, supported by the writings of Simone De Beauvoir. The book *The Second Sex* (1949) was a

phenomenological investigation of the 'woman' and the idea of womanhood. In the opening pages of the book, Beauvoir remarks:

"One is not born, but rather becomes, woman. No biological, psychic, or economic destiny defines the figure that the human female takes on in society; it is civilization as a whole that elaborates this intermediary product between the male and the eunuch that is called feminine. Only the mediation of another can constitute an individual as an Other. Inasmuch as he exists for himself, the child would not grasp himself as sexually differentiated. For girls and boys, the body is first the radiation of a subjectivity, the instrument that brings about the comprehension of the world: they apprehend the universe through their eyes and hands, and not through their sexual parts."

She differentiates the idea of sex from gender, providing these two terms with different meanings and explaining they are not synonymous. "Sex is understood to be invariant, anatomically distinct, and factic aspects of the female body, whereas gender is the cultural meaning and form that that body acquires, the variable modes of that body's acculturation" (Butler, 1986, 35). With this distinction, the presumption of any relation between sex and gender can be questioned. Moreover, social values or functions cannot be attributed to a particular sex. Being a woman and being female constitute two very different meanings, where one is a cultural interpretation, not the necessitated consequence of the other. Behaviour cannot be considered 'unnatural' or 'natural' if it doesn't fit into the preconceived notions of gendered behaviour.

Beauvoir placed great importance on the term 'become' which indicates that gender is not only imposed on identity but is a process in which the individuals construct themselves. In order to become a woman, the individual uses a set of appropriate acts, skills and behaviours to project a certain image. The image is perceived to be that of a woman as it is following the behaviours set by a society which classify one to be a man or woman. Beauvoir explains gender to be a tool of the patriarchy, which limits an individual to a certain role and creates a specific path to follow. Traditionally, women are sent down the path as homemakers and men as the breadwinners.

Dorothea Tanning agrees that the idea of womanhood is socially constructed rather than predetermined. She believes the 'gendering' is a violent process. She follows the statement with another line- "You may be a woman and you may be an artist; but the one is given and the other is you". (McCormick and Tanning, 1990. p. 39) The title of a 'woman' is ascribed by society and it is a role placed upon you. The individual has no choice or agency while choosing a gender, it is something assigned at birth. The title of an artist, however, is something that is achieved through the actions of the individual, making it something that is more personal and a choice. I will discuss the ideas presented by Simone de Beauvoir, and use them to understand and this lens to view Tanning's art.

Tanning provides a brief glimpse into her own childhood and experiences with gender hierarchy with her artwork *Family Portrait* (1954), where we see a family at the dinner table. The daughter and the father are shown to be sitting at the table, while the mother is standing with a plate of food. The father is wearing a black suit, glasses and a striped tie, and is depicted as a large and looming figure, almost three times larger than the woman. His figure even extends beyond the surface of the canvas. The women, who are painted to be smaller than the man, indicate the

patriarchy and the dominance of men over women in our society. Tanning describes her father to be a very authoritarian man in an interview with Marcel Duhamel. Duhamel refers to the *Family Portrait* and questions whether the characters are represented in proportion to the importance they had then in Tanning's eyes. Tanning replies saying "It is more generally a comment on the hierarchy within the sacrosanct family" (Duhamel, Tanning, 1977, 110). It is evident that Tanning was aware of the patriarchy and the hierarchical structure of society, as well as the importance of family roles. Ann Coxon, the co-curator of Tate Modern's show commented on the artwork of Tanning and describes it as something that "expands its legacy through its ongoing exploration of the same themes – like domestic and family life, flesh and bodies – to uncover the things that lurk in the shadows or behind the closed doors: the taboo".

A closer look into the domestic family life and Tanning's view of the oppression of women is provided through *All Hallows' Eve*, a poem written by Dorothea Tanning herself:

"Be perfect, make it otherwise.  
Yesterday is torn in shreds.  
Lightning's thousand sulfur eyes  
Rip apart the breathing beds.  
Hear bones crack and pulverize.  
Doom creeps in on rubber treads.  
Countless overwrought housewives,  
Minds unraveling like threads,  
Try lipstick shades to tranquilize  
Fears of age and general dreads.  
Sit tight, be perfect, swat the spies,  
Don't take faucets for fountainheads.  
Drink tasty antidotes. Otherwise  
You and the werewolf: newlyweds."

The poem revolves around a newlywed couple. Tanning uses metaphors of supernatural violence to illustrate the idea of domestic abuse, where the woman does her best to be 'perfect' in order to prevent the 'werewolf' (the husband) from abusing her. The woman in the poem is required to 'be perfect' or make herself perfect by sitting properly, and applying lipstick to 'tranquilize' the beast or herself. It shows the pressure to conform, and this demand extends to appearance, behaviour, and domestic roles. 'Fears of age and general dreads' can be seen as a commentary on the superficial aspects women have to focus on to be valued in society. Society often devalues and fears the aging of women, and pressurises women to remain youthful and attractive. She is required to appease her husband through these 'tricks' or faces the violent consequences described in the poem. She held a pessimistic view on the institution of marriage and painted it to be something shallow, where beauty and lipstick could be used to satisfy.

Tanning showed a dislike for socially constructed terms and roles associated with the institution of marriage or identity. She expresses her discontent with the term ‘woman artist’ and ‘wife of’ Max Ernst in an interview with John Glassie, in 2002. “If you get married you’re branded. We could have gone on. Max and I, all our lives without the tag. I never heard him use the word “wife” in regard to me. He was very sorry about that wife thing” she commented. “And ‘Woman artist’ Disgusting.” The patriarchy creates the need for establishing oneself as a woman artist, differentiating oneself from a man in order to gain independence or recognition. The label of a ‘wife’ is also a product of a patriarchal society and the dominance of men.

***Maternity (1946-47), Dorothea Tanning,***



*Maternity* (1946-47) provides further insight into Tanning’s idea of motherhood and the duties of women. It is an oil painting that depicts a figure, standing in a desert and clad in white. The figure wears an ankle-length, loose-fitting garment and can be identified to be a woman, a mother, who is holding onto her child. An open door can be seen behind the figure, and another one in front of her. Behind her, through the doorframe, we see an abstract figure that is comprised of ship masts and sails. The swell in the fabric resembles a woman’s pregnant stomach and breasts. It appears that the woman in the foreground has stepped through this door. Tanning has used dull colours of chrome yellow, grey, and blue to create a sense of distress or uneasiness which might reflect Tanning's own opinions on motherhood. “We might see the new mother in the painting as existing in a state of transition, having just gone through the door in the foreground which opens onto maternity”- she is ‘between lives’. What awaits her, beyond the next threshold, is a position in which she becomes all body- breasts, and womb- with no head or intellectual capacities, vulnerable to external forces rather than possessing any agency of her own" (Watz, 2022, p. 13). The weary mother wears an expression of resignation, where she gave up resistance against the patriarchal forces, and accepted her role in society- a mother or a wife, but not as an individual. Patriarchal forces enter into Tanning’s artwork by stepping through the thresholds of open doors.. The more open the door, the more complete the patriarchal control.

## Childish Resistance

Alyce Mahon, author, and curator, provides insight into the use of the femme enfant in the works of Dorothea Tanning. She writes “Tanning seemed to insist that the key to enlightenment was the *femme-enfant* who was not yet inhibited by society’s expectations and moral codes. Her female figures are poetic in their transformative powers and challenge fear and revulsion.”

As discussed earlier, the ‘Femme Enfant’ are figures seen frequently in the artwork of Dorothea Tanning. Another recurring motif is one of a door. She herself mentioned her frequent use of this object- “I do recall I had a dream about doors a long time ago, and those doors appeared in many canvases afterward.” This motif has a multifaceted meaning and is depicted in varying situations and settings. It invites viewers to come up with their own interpretations- whether it be of looking at it as a transition, both literal or metaphorical, a passageway into the unconscious or something that signifies liberation or an escape. However, I interpret the content behind the door to be some sort of confinement. It is something undesirable- the patriarchy, societal customs, and the forced gender roles that accompany sexual maturation. In this section, I will analyze the evolving relationship between the doors and the femme enfant to support my argument and interpretation.

Tanning suggests that feminist resistance can be the prevention of the opening of these doors. She indicates that perhaps it is best to let the dark, patriarchal forces behind the door stay where they are. She refers to one of her later pieces, *Door 84*, in an interview - “By this time, the door is the victim. Both people are pushing at that door. It’s being pushed by both sides. Maybe it never should open.” Tanning advocates an indifferent approach, one in which gendered roles, labels, and behaviours are left behind. In Tanning’s artwork, we see the femme enfant in different stages of life, in each the degree of patriarchal control varies. There is a distinction in the biological characteristics, as well the attire, hair, body language, and facial expression of the femme enfants. The level of patriarchal control goes hand in hand with the degree to which the door opens. When it is slightly open, the figures have their first encounter- puberty as seen in *Eine Kleine Nachtmusik*. As the door gradually opens further, they mature and become more aware of sexual knowledge and experience which is depicted in *The Guest Room* and *Birthday*. The doors open with age and act as transitions, passageways between the different stages of being and embracing a new, dark, or unknown phase of life. Opening the doors and stepping through them transforms ‘genderless’ figures or femme enfants into women such as the one seen in *Maternity*.

The painting *The Guest Room* (1952) features ajar doors, indicating to sexual knowledge and experience as well as encounters with the patriarchy and gender roles. *The Guest Room* shows an unsettling image behind a wide open door, we see a Caucasian, naked figure standing on the right side of the painting, in front of an open wooden door. Its feet are placed together and its arms are left hanging on each side of its body. The figure has the bodily proportions of a child, which lacks any identifying sexual features. The figure has blonde hair that has been tied up, and a face that doesn’t match the speculated age of the body. While the body looks like that of a child, the face holds an expression that resembles that of an adult. With pursed lips and eyes looking into the distance, it seems more experienced and troubled than a child would. The painting uses dull colours and an extreme amount of shadows to present, as Carruthers notes, gothic narratives and an enigmatic and



sinister scenery with connotations of sexual instigation. (Carruthers, 2011, pp. 141-142) “The painting alludes to nightmares: a dreamlike image of darkness versus the fragile image of puberty in a static narrative.” (Balsach, 2019, pp. 321) The painting exhibits the figures’ violent loss of control of their body through the invasion of their room by two hooded and faceless figures. They represent



the social interference in the lives of individuals, where children are forced to develop and undergo a process of gendering. The broken eggshells and uneasy mood of the painting hints that the procedure was aggressive and forced. In her oil on canvas artwork, titled *Children's Games* (1942) we see a long corridor, with an open door at the end, a symbol often seen in her other works. In the foreground, we see two children tearing down the grey wallpaper. The unusual characteristic here is that the dress on the first figure is backless, revealing the backside. This figure is wearing a set of black boots, while the second figure wears a greyish-white, frilly dress, paired with white-heeled shoes. The clothes make it evident that the figures belong to the bourgeois class, which reflects the background of Dorothea Tanning. The figures have features like

long blonde hair, fair skin, and tweedy bodies that are appropriate of Alice from Lewis Carroll's *Alice in Wonderland*. The long hair of one of the figures floats up and then into the wall, give a wonderland-esque feel to it where real life is merged with something extraordinary, and nightmarish. The torn wallpaper reveals sexual images. With reference to the lines said by Tanning- “I read somewhere that what I believed to be poetic and sublime testimonials of my conviction that life is a desperate confrontation with unknown forces are in reality cute girlish dreams, flaring with sexual symbols...” (*Women Artists in the Collection of the Musée national d'art moderne, Centre de création industrielle*, exhibition catalog, Paris: Centre Pompidou, 2009, p 37.) I believe this depiction to be one where the little figures are being exposed to the sexual world for the first time.

The fourth artwork I will mention is set in a long hotel hallway at the top of a flight of stairs. Four wooden doors stretch along the corridor, the last one being slightly open to reveal yellow light streaming through. In *Eine Klein Nachtmusik* (1943), we again see two figures, who can be classified as girls according to societal expectations. They are wearing frilly dresses, heeled shoes and have long, light-coloured hair. The attire and length of hair indicate they are girls; however, their body shows no sexual characteristics as they are shown to be flat-chested. These characteristics have led scholars like Paula Lumbar to assume them to be female children. These figures encounter a large sunflower, and the experience seems to be a violent one. “The child resting against the doorframe seems to have wrestled with the giant flower: pieces of the petals lie on the stairs, and she clutches some in her



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hands. Her small breasts are exposed as if some violent energy has torn open her blouse” (Lumbard, 1981, p. 52). The torn petals and the exhaustion written on their figures show that they have fought the sunflower. It symbolises their resistance and fights against their sexualisation. The painting radiates sexual energy and eroticism, particularly seen in the unbuttoned tops. As suggested by McAra, the flower symbolizes defloration or even menstruation. “The little girls' curiosity has brought erotic nocturnal knowledge” (McAra. 2011, p. 9).

The opening of the door shows an inflow of sexual knowledge and experience to the previously innocent figures. In this painting, the figures have adopted some of the customs that come with patriarchal notions that came through the door, as seen in their attire and hair. Tanning comments about this artwork in an unpublished letter to the Tate Collection- “It’s about confrontation. Everyone believes he/she is his/her drama. While they don’t always have giant sunflowers (most aggressive of flowers) to contend with, there are always stairways, hallways, even very private theatres where the suffocations and the finalities are being played out, the blood red carpet or cruel yellows, the attacker, the delighted victim...” (Tanning, 1999; Carruthers, 2011, p.146). Tanning’s words can allude to the first moments of confrontation- with carnal instincts and sexual identities or as Lumbard writes: “an initiation into puberty” (Lumbard, 1981, p.52). So this is not simply an introduction to sex, but to sexual violence

In *Birthday* (1942), a self-portrait of Tanning, we see a mature version of the femme enfant. Tanning paints herself in the foreground of a room, her hand resting on the handle of a door. The open door gives us a view of a hallway, filled with similar open doors. The background depicts a passageway of infinite open doors. The numerous open doors can signify numerous attempts to understand one's own identity, or the different challenges or paths the figure followed to reach the current destination. The multiple doors show multiple experiences with sexual themes and maturity. They could also symbolise a variety of roles that the figure has been forced to play each time it steps over a new threshold.



The figure in this painting seems to have matured physically, which can be interpreted through the exposed breasts. Along with the physical maturation, the expression of the figure shows weariness and experience. Tanning, in the painting, is bare-breasted, and barefooted. Thorns and long tangled roots emerge from her skirt and hang downwards. Her expression looks weary as if she appears to have returned or is beginning a troublesome journey (Lumbard, 1981, p. 51). The figure in this artwork is clothed in garments that can help identify it to be a woman. She has sexually matured and has been socialised into dressing like a woman. However, the process of socialisation seems incomplete as she has not yet understood and followed all the norms of society. Her breasts remain uncovered— which is something that remains a taboo in society. She seems to be undergoing a process of transformation, which is supported by the



title of the artwork and by the symbolism of the figure next to her feet (Lumbard, 1981, 51). The unfamiliar animal near her has been identified as a winged lemur by art historian Whitney Chadwick. The creature seems to have also undergone a journey and is in a state of life transformation as it is a composite of many animals. The exposed, mature breasts, skirt, and hairdo indicate that Tanning in the image has ‘become a woman’ or is undergoing the process of becoming one.

The last artwork that I will discuss is *Door 84* (1984). It is deep deep-hued, fluid and abstract painting of Dorothea Tanning. It makes use of vibrant yellow, chrome and blue. The fluid strokes blur the lines between a dreamlike world and external reality. In this piece, we see a single door, one that is firmly shut. The reason this artwork is first discussed is due to this state of the door, as well as the physical depiction of the femme enfant. There are two femme enfants in this image, one on each side of the white door. Both figures are pushing at the door, forcing it to remain shut. The first is wearing a light-coloured, loose garment that hides all sexual characteristics. Its figure lacks any sort of gender-affirming features, and its

*Door 84, Dorothea Tanning (1984)*



garments don’t hint toward a gender as well. It is in a lunge position, with one leg on the door and the other on the ground. Both hands are pushing the door and the head is bent. The figure on the right gazes toward the viewer, head slightly bowed as the leg is outstretched and pressed up against the door. The belly is painted green, providing some depth to the image and hinting that the figure is pregnant. From a glance at their body language, one can easily say they are trying to keep the door closed and prevent a transition or crossover from

taking place. I understand this to be an attempt to resist the patriarchy and the gender norms that come with it. In this resistance, we see a sense of solidarity amongst the figures. Both make an attempt to keep the patriarchal forces at bay. In the face of patriarchy, Tanning highlights, it is important to unite in order to achieve liberation from oppressive constructs.

When the door is slightly open, the figures have their first encounter- puberty or even sexual violence as seen in *Eine Kleine Nachtmusik*. As the door gradually opens further, they mature and become more aware of sexual knowledge and experience which is depicted in *The Guest Room* and *Birthday*. The doors open with age, and act as transitions, passageways between the different stages of being and embracing a new, dark, or unknown phase of life. As seen in *Maternity*, opening and stepping through the door transforms genderless figures or femme enfants. In the words of Simone de Beauvoir, they are “made a woman.” As seen in *The Guest Room*, patriarchal forces often force their way into our lives and assert dominance and authority over our actions and behaviour. Tanning urges resistance against these corrupting and gendering forces. She encourages the viewers to remain on their side of the threshold to preserve their agency and control over their own bodies.

Tanning urges us to resist patriarchal forces by resigning from forced, patriarchal roles. Tanning resisted these forces by rejecting the title of 'woman' and 'wife' of Max Ernst, instead advocating for individual freedoms through her artwork.

## **Conclusion**

In conclusion, this research has illuminated the role of Dorothea Tanning's art in challenging patriarchal notions regarding gender and sexuality. Her use of the doors and femme enfant motif have been tools for a critique of conventional gender roles and the social control of behaviour. In her art, it becomes evident that the act of opening the door can usher in unwanted patriarchal forces that threaten to diminish the autonomy of women and their control over their own bodies. Tanning observes that perhaps the door should remain shut to prevent the disempowering and exposure of femme enfants to oppressive roles. The femme enfant archetype, as depicted in Tanning's work, calls for the reevaluation of gender roles and the idea of doors acting as portals to liberation and self-discovery. The study prompts exploration into the interplay between societal norms and art, offering future research on themes of gender in art, as well as a catalyst for social change. It encourages artists and scholars to continue to push the boundaries of creative expression and analysis. It prompts us to reconsider the doors we open and the forces we allow in.

## Works Cited

- Balsach, Maria Josep. "Visions from the Desert. The Metamorphoses of Dorothea Tanning." *Barcelona Research Art Creation* 7, no. 3 [June 2019]: 307–35.
- Beauvoir, Simone de. *The Second Sex*, 1949.
- Breton, Andre. "What Is Surrealism." Lecture, June 1, 1934.
- Butler, Judith. "Performative Acts and Gender Constitution: An Essay in Phenomenology and Feminist Theory." *Theatre Journal* 40, no. 4 [1988]: 519–31.  
<https://doi.org/10.2307/3207893>.
- Carruthers, Victoria. "Dorothea Tanning and Her Gothic Imagination." *The Journal of Surrealism and the Americas* 5, no. 1 [2011].
- Carter, Angela, and Xavière Gauthier. "Angela Carter and Xavière Gauthier's Surréalisme et Sexualité Get Access Arrow." *Contemporary Women's Writing* 4, no. 2 [July 1, 2010]: 114–33. <https://doi.org/https://doi.org/10.1093/cww/vpp020>.
- Duhamel, Marcel, and Dorothea Tanning. *Other*, 1977.
- Glassie, John. "Salon," February 11, 2002.
- Kahlo, Frida. "Two Nudes in a Forest," 1939.
- Klingsöhr-Leroy, Cathrin, 2004.
- Lumbard, Paula. "Dorothea Tanning: On the Threshold to a Darker Place." *Woman's Art Journal* 2, no. 1 [1981]: 49–52. <https://doi.org/https://doi.org/10.2307/1357902>.
- McAra, Catriona. "Surrealism's Curiosity: Lewis Carroll and the Femme-Enfant." Thesis, Papers of Surrealism, 2011.
- McCormick, Carlo, and Dorothea Tanning. "Dorothea Tanning." *BOMB*, no. 33 [1990]: 36–41.  
<http://www.jstor.org/stable/40424069>.
- Tanning, Dorothea. "Birthday." 40 1/4 x 25 1/2 in., 1942. Philadelphia Museum of Art.
- Tanning, Dorothea. "Children's Games." 11 x 7 1/16 in., 1942.
- Tanning, Dorothea. "Door 84." 63 3/4 x 104 x 5 1/4 in., 1984.
- Tanning, Dorothea. "Eine Kleine Nachtmusik." 16 1/8 x 24 in., 1943. London.
- Tanning, Dorothea. "Portrait de Famille [Family Portrait]." 39 3/8 x 31 7/8 in., 1953. Musée National d'Art Moderne. Centre Georges Pompidou, Paris.
- Tanning, Dorothea. "The Guest Room." 60 5/16 x 42 1/4 in., 1952.
- Watz, Anna. "Maternities: Dorothea Tanning's Aesthetics of Touch." *Art History* 45, no. 1 [February 16, 2022]: 12–34. <https://doi.org/https://doi.org/10.1111/1467-8365.12631>.

## **Enhancing Women's Market Access in India By Anvi Singh**

### **Abstract**

This study analyzes the effectiveness of two strategies in India, "working with your people" and "market protection"; it examines the impact of trade policies on improving women's market access. This research methodology is based on quantitative and qualitative data from relevant sources such as government reports and involves a comparison of two policy approaches.

### **Introduction**

Women's economic empowerment is a matter of social justice and a key driver of sustainable development. In recent years, the pivotal role of women in promoting economic growth and inclusive development has been increasingly recognized.

According to the World Trade Organization, women-owned enterprises account for about 36 percent of all micro, small, and medium-sized enterprises worldwide. Despite this significant presence, women entrepreneurs face many challenges in accessing domestic and international markets. Trade policy has the potential to influence market dynamics and is crucial in unlocking women's full economic potential.

### **Purpose**

This study examines trade policy focusing on India's approach to improving women's market access. By comparing the effectiveness of two policies, "Working on your people" and "Protection of markets," we seek to uncover the secrets behind policy effectiveness and determine the most promising approach for a gender-inclusive future

### **Analysis**

The Handloom Reservation Act (HRA) introduced in 1985 is one of the many policies made to protect India's market. There are many objectives that the HRA Act touches on, but our main focus is on the Socioeconomic welfare and the promotion of India's handloom industry.

**Socio-Economic - The HRA** focuses on the socio-economic well-being of handloom weavers and their communities. The law ensures the survival of hand looms and guarantees constant demand for products with hand looms by providing a market guarantee for products reserved with hand looms. This, in turn, promotes poverty alleviation, empowerment of artisans, and socioeconomic development of the entire craft cluster.

**Promotion of India's handloom industry -** This Act played an important role in the promotion of the Indian craft industry both nationally and internationally. By reserving certain handloom products, the Act helps create a clear identity for handloom products in India and highlights their cultural and artistic importance. The campaign promotes growth and awareness of the Indian textile industry, which is improving its market share and competitiveness.

The HRA aims to prevent unfair competition from powered or mechanized production. By reserving certain handloom articles exclusively for handloom weavers, it ensures that handloom products have a distinct identity and market niche. This protection helps maintain a level playing field for handloom weavers, preventing the dilution of their market share through mass-produced alternatives, for example, saris, dhotis, and lungis (traditional Indian wear), these products are reserved for production by handloom weavers in India, and cannot be produced by power looms or other mechanized machines.

This policy contributed to the expansion of India's craft industry. The sector employs 43.31 million people engaged in about 23.77 million manual jobs, of which 10% are from castes, 18% from tribes, and 45% from other backward sectors. The growth rate of the textile industry itself is estimated around 14.8% from 2021-2025, and the market size is estimated to be 220 billion U.S dollars.

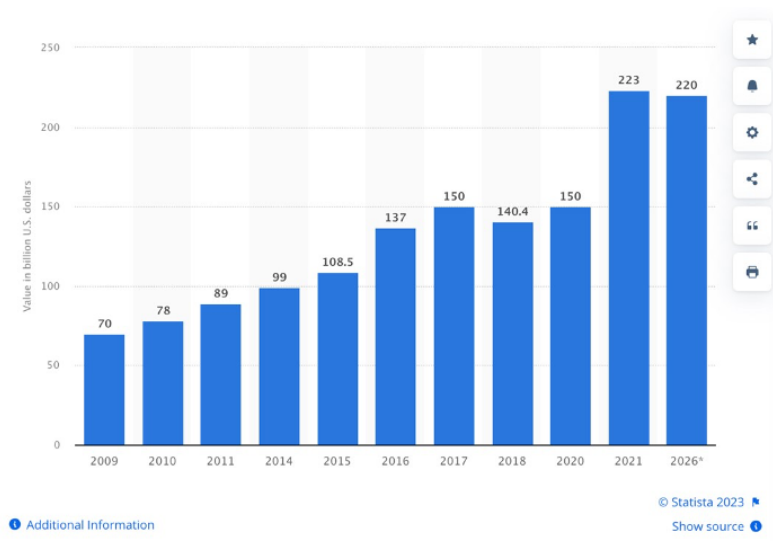


Diagram 1: Shows the growth of the Indian craft industry in India (billion U.S dollars) Almost 15% of the country's textile production is produced in this industry, which also benefits the country's export earnings.

Before the HRA 1985 came into force, the Indian textile industry faced many challenges. Lack of Market Access - Weavers faced challenges in accessing markets outside their immediate area. Limited infrastructure, lack of marketing support, and lack of presence in both urban and international markets have limited our ability to promote and sell our products. This lack of market access limited the growth potential of the industry and weakened the economic prospects of weavers, including women.

Disregard for traditional crafts - The decline in demand for handwoven products has led to a loss of appreciation for traditional crafts and weaving techniques. This neglect threatened the preservation of cultural heritage and endangered the livelihood of skilled artisans, especially women, who were traditionally involved in hand weaving.

The difference between the growth in production and the market turnover after the HRA can clearly be seen in the table below.

Sr. No	During 5th plan as on 31.3.80	During 6th Plan as on 31.3.85
1. No. of handlooms	30.20 lakhs	30.20 lakhs
2. Total Production of handloom fabric	2900 million mts.	3600 million mts.
3. Handlooms brought under the cooperative fold	13.17 lakhs	18.00 lakhs
4. Share capital assistance to apex societies	Rs. 11.25 crores	Rs. 11.30 crores
5. Share capital assistance to Handloom Development Corporation	Rs. 6.76 crores	Rs. 10.62 crores
6. Rebate	Rs. 9.23 crores	Rs. 43.40 crores
7. Subsidy on production of Janata cloth	Rs. 36.03 crores	Rs. 225.09 crores
8. Modernization of looms (in numbers)	---	1,18,000
9. Processing facility	Rs. 7.15 crores	Rs. 9.15 crores
10. Credit received from financial institutions	Rs. 147.22 crores	Rs. 596.00 crores
11. Market turnover of State Apex Coop. & HDC	---	Rs. 480.00 crores

Source: Indian Textile Journal, No.1, 1985.

Diagram 2: Shows the growth of the textile industry after the HRA was implemented.

Located in Jharkhand, India, Jharcraft is a state-owned company that is a significant factor in advancing the region's handicrafts and the handicraft industry. To give rural Jharkhand's weavers and artisans access to sustainable livelihoods, established in 2006.

One of the main objectives of Jarcraft is to revive and promote the craft and handicraft traditions of Jharkhand. The company works closely with local artisans, providing training, design input, and market links to improve their skills and empower them to create quality handwoven products and crafts.

Jharcraft has benefited from the HRA, according to the Jarcraft website, the company works with more than 32,000 local artisans and weavers in Jharkhand, and about 1,370 people from rural areas in and around Jharkhand have been trained in various crafts under the CSR initiative to make them self-reliant, including significant number of women.

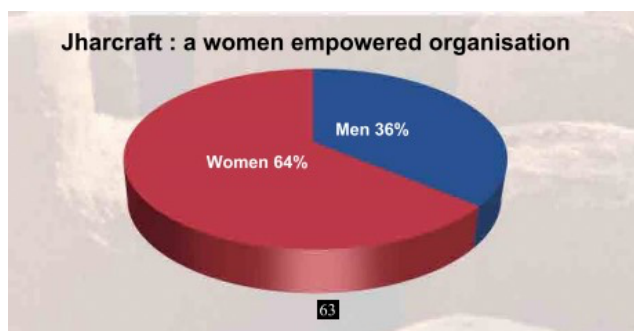


Diagram 3: Shows the female-to-male ratio of people empowered in Jharcraft.

The company has also increased significantly, as in the year 2013-2014, the reported turnover was 53 lakhs and the exported products in 2013-2014 were worth 1 crore. The HSR Act helped protect India's domestic market for handwoven products and benefited Jarcraft by

creating a market for locally made products. This policy contributed to the growth of the handloom industry in India by increasing the demand for locally made products by reserving the production of certain handloom products in India exclusively as handicrafts.

The growth of organizations like Jharcraft focused on promoting handwoven products and empowering artisans has undoubtedly played a key role in increasing women's market access in the handwoven industry, even though there has been no subsidy provided to Jharcraft from the government, Jharcraft is still promoted by Kusum Emporium, which is a registered body under the Jharkhand State Cooperative Societies Act, 1935, showing that a government had a little part to play in the growth of Jharcraft and in the growth to empowering women's market accesses in the global playing field, as well as through training, resources and market links, these organizations have helped artisans improve their skills, improve the quality of their products and access larger markets.

Organizations like Jharcraft have helped artisans to create awareness and better market opportunities for handwoven products through capacity building, design, and marketing promotion. This not only improved their economic opportunities but also helped preserve and promote their traditional crafts and cultural heritage.

Even though Jharcraft is not a company that only helps women, the market linkages and export promotions help women access the global market more easily, Jharcraft actively promotes the creation of a market network of women artisans and connected them with domestic and foreign buyers and exporters. By participating in fairs, exhibitions and buyer meetings, Jharcraft provides a platform for artisans to showcase their products and build business relationships with potential buyers in the global market.

Overall, due to the HSR policy which help to promote Jharcraft, and even though there is on significant data that Jharcraft helped women gain more access to the global playing felid, it is clear that Jharcraft has grown as a company, alongside the textile industry, and since it is clear that more women are empowered with Jharcraft it is fair to conclude that women have been empowered through the policy and company and as stated Jharcraft holds a platfrom where the artisans can build business relationships with potential buyers in the global market, concluding that women have been empowered.

### **Analysis of Government Promoting Entrepreneurship for Women**

The Indian government has launched several programs across India to empower women in various ways including loans. These programs are based on the recognition that women's economic empowerment is a key aspect to enabling and achieving gender equality.

The main goal of these programs is to encourage women to start their own businesses and provide them with the support they need to succeed. This support includes access to finance, business development services, skills development programs mentoring, and networking opportunities. Addressing the unique challenges women entrepreneurs face, such as limited access to capital, lack of support systems, etc.

These programs facilitate access to global markets by providing women entrepreneurs with the necessary skills, knowledge, and visibility. By participating in international business events and networking, the women entrepreneurs contacted potential buyers, investors, and partners around the world. This has made it easier for companies to access global supply chains and export their products and services, which has improved their competitiveness in international markets.

According to a recent survey done by "The Times Of India", the number of women-owned businesses in India increased by over 20% in the last five years, but still according to IMF (International Monetary Fund) only 14% of enterprises in India are women owned, which when worked out is 8 million women, so this brings us to think about how significant the schemes are when empowering women and allowing women to access the global market.

Even though there might not be multiple women in the economics playing field right now according the a GEM India report women entrepreneurs in India have seen to help a growth in the economy and also shows that women entrepreneurs are not limited to small businesses only.

Monetary Fund (IMF), investing in women entrepreneurs can contribute more towards a gradual shift in the society, better education and a healthy environment in the country. Currently, the maximum count of women entrepreneurs has increased in the MSMEs. As per reports, India records 15.7 million women-owned MSMEs and agribusinesses in India. Today women entrepreneurs in India are not limited to small businesses. Breaking the glass ceiling, some women have created some of the most successful startups which are generating annual turnover in crores.

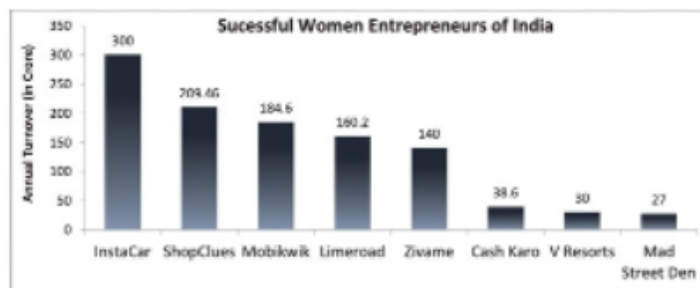


FIGURE 1.4 Successful Women Entrepreneurs in India  
Source: Software Success.com

Diagram 4: Shows the number of successful female entrepreneurs in India and how much their annual turnover is in crores.

Women entrepreneurs are building innovative businesses, leveraging technology, and serving the needs of diverse markets. These startups cover areas such as healthcare, education, sustainability, and social impact, and one of the main reasons for more women to join the startup market is because the government is providing multiple women to take simple loans for diverse reasons.

Even though India might not see direct results from these schemes, there are multiple benefits of these schemes. One of the schemes is MUDRA Yojana. MUDRA (Micro Units Development and Refinance Agency) Yojana is a scheme launched by the Government of India



in 2015 to provide financial support for micro-enterprises and promote entrepreneurship in the country.

The main objective of MUDRA Yojana is to provide financial assistance to unaffiliated nonagricultural SMEs/micro-enterprises. These businesses typically include small businesses, traders, artisans, and individuals engaged in various small-scale activities. The program targets people who need help to obtain formal credit through traditional banking channels.

The MUDRA Yojana has grown in many factors from other loan lending companies, an example of growth in the MUDRA Yojana is,

MUDRA Yojana has introduced a simplified credit application process that makes it easier for entrepreneurs to get credit. The program offers its three loan categories Shishu, Kishore, and Tarun to meet different financial needs at different stages of business growth. This simplified process resulted in more people using the formal credit system.

Apart from the loans, MUDRA Yojana also provides refinancing support to financial institutions such as banks, non-banking financial institutions (NBFCs), etc. With this support, financial institutions have enough money to lend to small businesses, creating a sustainable lending ecosystem.

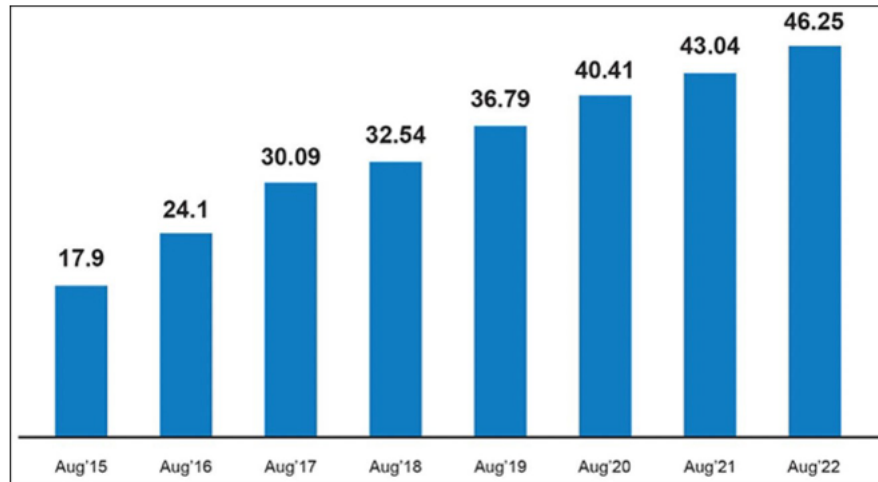
Loans under the MUDRA Yojana are collateral-free, meaning that the borrower does not have to put assets as collateral. The interest rates of these loans are competitive and affordable, making them accessible to small businesses.

MUDRA Yojana offers loans to eligible individuals and companies in three categories or tiers depending on their financial needs.

- Shishu (up to Rs.50,000): This category is for companies or individuals seeking small finance to start a new business.
- Kishore (Rs 50,001 to Rs 50,000): This category is suitable for companies or individuals who have already started their business and need financing for expansion or growth.
- Tarun (Rs. 500,000-Rs. 1,000,000): This category is for companies that want to get higher loan amounts to further improve their operations.

To facilitate access to credit, MUDRA Yojana works with various financial institutions such as commercial banks, local regional banks, and microfinance institutions. These institutions act as intermediaries and offer loans to eligible borrowers.

According to the IAS Parliament “In 2022 disbursements of loans to women entrepreneurs registered an average growth of 28%.”, the MUDRA Yojana., according to ORF Between 2014 and 2017, the gender gap in account access in India fell from 20 to 6 percentage points, due to the PMJDY, a loan scheme used is the MUDRA Yojana, and the figures from year 2022 show that 55% of the account under PMJDY are under women.



Source: Ministry of Finance

The PMJDY initiative was backed by efforts from the government to help women obtain basic bank accounts. First of all, it dispenses with lengthy paperwork, helping expand the outreach to those who faced issues of illiteracy. Figures from 2022 show that more than 55 percent of accounts under PMJDY are held by women.<sup>[17]</sup>

Diagram 5: Shows the PMJDY account in crore, with the description of how many women own the account

While the MUDRA Yojana has made progress in helping Indian female entrepreneurs enter the global market, it is important to recognize that challenges and barriers still exist that prevent women from fully participating in the global market. . . However, it is also important to understand that even incremental progress has positive effects. It provides financial support, and unsecured loans to women entrepreneurs to start and grow their businesses. This has opened up opportunities for them to enter the global market.

The impact of the MUDRA Yojana may not be as transformative as many hoped for, but it is a step in the right direction. Any empowerment of women and their access to global markets is a positive development and another step towards improving opportunities for women in India

## Conclusion

In conclusion, both the MUDRA Yojana and Jharcraft have proven to be effective methods to promote women's market access and have had a positive impact on their specific targets.

MUDRA Yojana facilitated the financing of women entrepreneurs through comprehensive loan disbursements and a simplified loan process. The program focuses specifically on women-owned businesses and has played an important role in promoting gender equality and the economic empowerment of women. The growth of MUDRA Yojana promotes

financial inclusion, job creation, and economic growth that positively impact the lives of women entrepreneurs.

Similarly, Jarcraft, an initiative of the Jharkhand government, promoted market access for women artisans and weavers. Jharcraft empowers women to showcase their skills and reach a wider market by providing training, design support, and marketing support. This initiative enabled women to earn a living, preserve traditional crafts, and gain recognition for their profession.

Both initiatives were recognized for helping women entrepreneurs and artisans by addressing the specific challenges they face when entering the market. They provide targeted intervention, financial support, skills development, and marketing assistance to help women break barriers and achieve success in their respective industries.

The impact goes beyond financial impact. It also contributes to the development of society by promoting gender equality, preserving cultural heritage, and empowering women to take responsibility for their lives and futures.

In conclusion, the MUDRA Yojana and Jharcraft represent commendable efforts to promote women's market access and have shown a positive impact on the target women. These efforts are valuable models for other regions and sectors and emphasize the importance of individual actions to increase the economic empowerment of women and promote inclusive and sustainable development.

### Works Cited

- Bain & Company and Google. *Powering\_the\_economy\_with\_her*. 2019.
- Bosma, Niels , et al. *Global Entrepreneurship Monitor*. 2020.
- Delhi, PIB. “More than 37.76 Crore Loans Amounting to over Rs. 20.43 Lakh Crore Disbursed since Inception of Pradhan Mantri Mudra Yojana.” *Pib.gov.in*, 12 Dec. 2022, [pib.gov.in/PressReleaseIframePage.aspx?PRID=1882885](http://pib.gov.in/PressReleaseIframePage.aspx?PRID=1882885).
- IAS Parliament. “Evaluation of PM MUDRA Yojana | Current Affairs.” *Www.iasparliament.com*, 2023, [www.iasparliament.com/current-affairs/evaluation-of-pm-mudra-yojana](http://www.iasparliament.com/current-affairs/evaluation-of-pm-mudra-yojana). Accessed 6 Aug.2023.
- JHARCRAFT. “JHARCRAFT – Jharkhand Silk Textile & Handicraft Development Corporation Ltd.” *Www.jharcraft.in*, 2006, [www.jharcraft.in/](http://www.jharcraft.in/). Accessed 6 Aug. 2023.
- Kuadli, Jenifer. “Women Entrepreneurs Statistics.” *Legaljobs.io*, 20 May 2023, [legaljobs.io/blog/women-entrepreneurs-statistics/](http://legaljobs.io/blog/women-entrepreneurs-statistics/).
- Kumar, Debosmita Sarkar and Sunaina. “Women-Centric Approaches under MUDRA Yojana: Setting G20 Priorities for the Indian Presidency.” *ORF*, 2022, [www.orfonline.org/research/womencentric-approaches-under-mudra-yojana/](http://www.orfonline.org/research/womencentric-approaches-under-mudra-yojana/).
- Malik, Vipin. *Rev-Textile - Final*. 2023.
- MUDRA Yojana. “Mudra - Micro Units Development & Refinance Agency Ltd.” *Mudra.org.in*, 2015, [www.mudra.org.in/](http://www.mudra.org.in/).
- Pandey, Nishtha. “Women & Entrepreneurship in India 2019: Our New Study Uncovers What Women Need to Flourish.” *Women’s Web: For Women Who Do*, 16 July 2019, [www.womensweb.in/2019/07/women-entrepreneurship-in-india-2019-our-new-study-uncovers-what-women-need-to-flourish/](http://www.womensweb.in/2019/07/women-entrepreneurship-in-india-2019-our-new-study-uncovers-what-women-need-to-flourish/).
- S. SUDALAIMUTHU, DR. “Handloom Industry in India - Free Industry Articles - Fibre2fashion.com.” *Www.fibre2fashion.com*, 2007, [www.fibre2fashion.com/industry-article/2269/handloomindustry-in-india.SEWA.‘Home.’SelfEmployedWomen’sAssociation,1972,www.sewa.org/](http://www.fibre2fashion.com/industry-article/2269/handloomindustry-in-india.SEWA.‘Home.’SelfEmployedWomen’sAssociation,1972,www.sewa.org/).
- SOUNDARAPANDIAN, DR. M. *Growth and Prospects of Handloom Sector in India*. 2002.UNCTAD, et al. *Desk Study on the Gender Aspects of Trade and Trade Policy for Statistics*. 2023.
- Valenti, Fabrizio. *WOMEN ENTREPRENEURS as the POWERHOUSE of RECOVERY*. 2020.

# **A Comprehensive Review of Techniques Used in researches on Foraminiferal Indicators of Paleoclimate By Doyeon Myeong**

## **Abstract**

Fossils of foraminifera, a protozoa that first appeared in middle Cambrian and still thrives on to today, are a widely used proxy in paleoclimate studies. However, while many researches on foraminifera in paleoclimatology are being conducted, few of the papers have concentrated on the trends of research methods and each of their limitations. Thus, each technique of foraminiferal research lacks a precise knowledge of its advantages, and specific disadvantages that should be implemented in the future.

This comprehensive review paper summarizes and evaluates various technologies and methods used in the foraminiferal approach in paleoclimatic research over the past five decades, spanning from the 1970s to 2023. The review not only recognizes the development and trends in foraminiferal research but also identifies weaknesses in past studies and technologies and proposes strategies for enhancing these methodologies, aiding better understanding of foraminiferal research.

## **Introduction**

In the mid-20th century, the academic area of paleoclimatology emerged. Paleoclimatology, a study of past climates of earth, involves the investigation of ancient climate conditions, variations, and changes that occurred over geological time scales. Until now, Paleoclimatology has played a crucial role in understanding natural climate variability and the impacts of human activities on the Earth's climate system. This knowledge has informed past climate change policy and mitigation efforts.

Paleoclimatic research is based on various climate proxies such as pollen, volcanic ash, nite, and marine microorganisms. Among these, foraminifera is viewed as one of the most intriguing candidates due to its spatial constraints, capacity for observing detailed and gradual changes, and ability to measure environmental shifts over extended periods. Through the analysis of paleoclimatic research methods using foraminifera, this paper aims to analyze the trend of changes in methods used in three types of foraminifera research technique - morphological investigation, element ratio measurement, genetic approaches - and to present ways to compensate for the weaknesses of current methodological limitations.

## **Method**

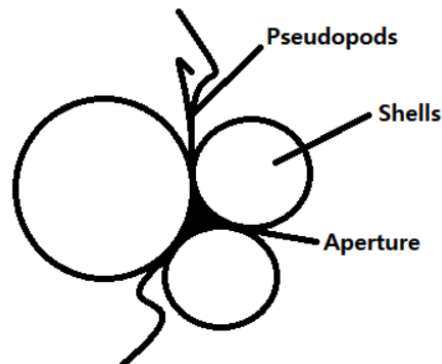
Articles in this literature review were found in two databases, SCIENCE and Google Scholar, using the keyword 'foraminifera.' One to three articles from each decade were selected from each database based on their Impact Factors and relevance. A total of 28 articles for comprehensive analysis were collected, with 5 more articles for supplementary materials.

## **Importance of Foraminiferal Research**

Among paleoclimatic proxies, foraminifera are currently one of the most researched proxies because of their aptness in research. First, because foraminiferal evolution occurs at a rapid rate compared with other species, its change in morphological shape over a relatively short period can indicate fluctuations in climate change in the given area. Second, because its population is massive and its habitat is widespread from Arctic seas to equatorial seas, the technique of using foraminifera as a paleoclimatic indicator can be used in such a wide geographical investigation site. Third, the unique shells in benthic foraminifera contain calcites and various elements found in the seabed, which can be used as an indicator of the marine environment. Finally, descendants of foraminifera still live on, making it comparatively easy to trace the phylogenetic tree or determine which traits evolve under these conditions. Because of such benefits in foraminiferal research, the study of foraminifera has become one of the major areas of study in both micropaleontology and paleoclimatology.

### Characteristic of Foraminifera

Foraminifera are amoeba-type protozoans and are widely distributed in various marine environments from the seabed to the surface layer, coastal to deep sea, and equator to polar regions (Murray, 2006; Hayward, 2020). It is different from other protozoans in that it has a thread-shaped gastric network called pseudopods that can be attached to a relatively large single-celled animal and a shell of secretions with various components and shapes.



**Figure 1.** Simplified structure of foraminifera

Foraminifera have a granular-reticle gastric group and form a single or multiple outer shell made of grains such as calcium carbonate or mineral particles from the surrounding environment. The shell of the foraminifera is about 0.01~190  $\mu\text{m}$ , and can be classified into calcite, chitin, slice, and siliceous shells made by attaching different types of external particles. Among those, calcite shells are exclusively found in benthic foraminifera and are widely used for extracting remaining elements and calculating temperature for paleo oceanic environments.

The outer shell formed in this way can be fossilized and preserved in the geological layer even after the foraminifera die (Holbourne, 2013; Hayward, 2020). The fossil record of foraminifera began in the Cambrian period more than 525 million years ago and has evolved and continued to thrive until today (Gupta, 1999).

Because foraminifera fossils are often contained within glacial or mud cores, the chores of ejecting cores from sea basins or glacial sites are often used in foraminiferal research. However, since this procedure is not only unique to foraminifera but also carried out in various marine microorganisms, this process will not be covered in this paper.

Since d'Orbigny first established the foraminifera tree in the early 19th century and proposed the first taxonomic system (Gupta, 1999; Pawlowski, 2013), the composition of the outer shell, structure, coiling directions, number of internal chambers, arrangement of internal chambers, and shape and location of openings have been important criteria for the morphological classification of foraminifera. According to the existing literature and the World Register of Marine Species (WoRMS), foraminifera are currently taxonomically accepted at the phylum level (Holbourn, 2013; Hayward, 2017), and approximately 10,000 modern species, including 40–50 planktonic species, have been reported worldwide (Gupta, 1999; Murray, 2007).

Studies that identify the paleoclimate due to the morphological fossils of foraminifera have two different steps. First, the samples are sieved and sampled, and second, it goes under the microscopic analysis.

### **Sieving and sampling the fossils.**

Sampling the fossils often include the procedure of sieving, getting rid of the impurities by the water pressure mechanism, and the process of drying the fossils without any distortion of the figure. Although the observation of morphology of the foraminifera fossils started in the late 19th century, most of the research conducted from 1970s to 2020s use similar sieving and sampling techniques of foraminifera fossils. The procedure is as followed:

(1) Sieving involves the utilization of fine-mesh screens to sift sediment samples obtained from geological formations or ocean floor sediments. This process allows for the separation of foraminifera fossils from the surrounding matrix, which may consist of sand, silt, or clay; (2) Placing the core pieces on the wet wash sieve, slight water is added for better separation of core sediments. Then, the researcher or a mechanical sieve shaker shakes the sieve so that silts, clays, and any other impurities smaller than desired foraminifera fossils can be washed off (3) While conducting sieving, the choice of mesh size is crucial, as it determines the size range of foraminifera that will be retained. Fine-mesh sieves with openings typically ranging from 32 micrometers ( $\mu\text{m}$ ) to 63  $\mu\text{m}$  are widely used. (3) Also, how the sieve is woven may also contribute to the resulting ratio of remaining foraminifera fossils. Using different sieves often result in different features of found population of foraminiferal fossils;



**Figure 2.** Sieving process of foraminifera fossils (*Micropaleontology Lab - GEOMAR - Helmholtz-Zentrum Für Ozeanforschung Kiel.*  
[www.geomar.de/en/research/fb1/fb1-p-oz/infrastructure/micropaleontology-lab.](http://www.geomar.de/en/research/fb1/fb1-p-oz/infrastructure/micropaleontology-lab.))

Overall, the process of sieving and sampling the fossils is quite lengthy, and depends overly on the tools like sieve and shaker, introducing bias to the remaining data. While this classical methodology is reliable to use for more than centuries, there seems to be a need to improve such procedures in morphological research.

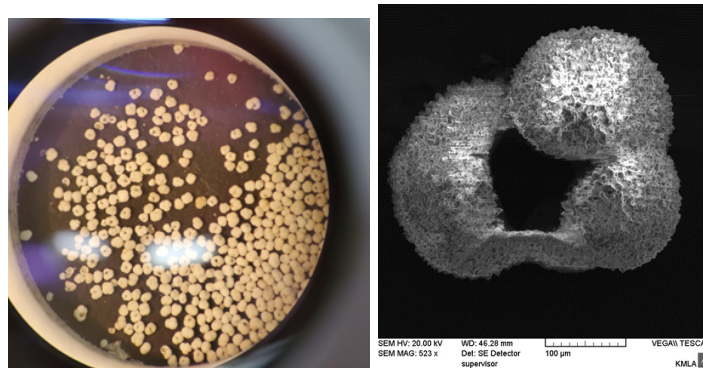
### **Microscopy**

After sieving and getting purified foraminiferal fossils, researchers should observe and record the foraminiferal fossils found in the core. There are some selections of microscopy for foraminifera fossil observation:

(1) Light microscopy is a first step of conducting microscopy on a provided sample. Although it does not magnify the fossils in great details, researchers can easily identify and carefully pick out individual complete foraminifera fossils worth researching under light microscopy; (2) TEM is used to inspect the internal cell structure of foraminifera fossils and measure the thickness of the shells; (3) SEM is used to observe external shell structure of foraminifera fossils, and is more widely used than TEM. Since the species can be easily be specified with the external feature of foraminifera, one research even aimed to make an AI algorithm of detecting SEM image of certain foraminifera and determining its genus and species(Sanghun Shin, 2004);

The process of using microscopy to determine morphological features of foraminifera can result in detailed analysis of each specimen found in specific cores, leading to advanced research in taxonomy and deduction of paleoclimatology over it. However, the fact that detailed observation must be done under TEM and SEM, which is far more expensive and difficult in handling the light microscopy, and the limit of sample size that could be analyzed under a microscopy may restrict the spatial and temporal resolution of paleoenvironmental reconstructions.





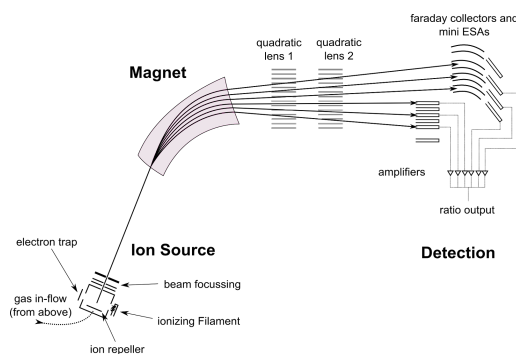
**Figure 3.** (Left) Light microscopy of plankton foraminifera *G.bulloides*. **Figure 4.** (Right) SEM microscopy of plankton foraminifera *G.bulloides*

### Techniques of measuring elemental ratio in foraminiferal shells

Techniques that measure the elemental ratio inside foraminiferal shells aim to provide information about paleoclimatic conditions based on the amount of element which benthic foraminifera and stored in its shell. Although morphological strategies have been introduced first, it is now considered the most accurate technique for determining the exact change in temperature scales.

### Utilization of elemental isotopes

First introduced in the mid-1970s, investigation of the  $^{16}\text{O}/^{18}\text{O}$  ratio is now the most popular method for determining past temperatures because the weight difference between two isotopes results in a slightly different portion in the atmosphere in different temporal situations. It was first popularized among the paleoclimatologists in the late 1980s, and constantly used until 2020. The oxygen and carbon used in the experiments were concentrated in calcite( $\text{CaCO}_3$ ), which comprises foraminifera shells. For this, the process of grinding foraminiferal shells and dissolving them in hydrochloric acid to obtain gaseous elements is crucial. After this, IRMS (Isotope Ratio Mass Spectrometer) calculates the ratio of each isotope and yields data.



**Figure 5.** General structure and mechanism for IRMS(*Introduction to IRMS.*  
[www.nu-ins.com/products/irms/introductiontoirms.](http://www.nu-ins.com/products/irms/introductiontoirms.))

The ratio between the two oxygen isotopes inside the foraminiferal shell can be used to identify the paleoclimatic temperature because of their weight difference. When the temperature is very low, both  $^{18}\text{O}$  and  $^{16}\text{O}$  remain about the same ratio in seawater. However, when the temperature increases,  $^{16}\text{O}$ , a slightly lighter isotope, evaporates more rapidly into the atmosphere via water molecules. Thus, by investigating the rate between the two different isotopes and placing the ratio into the calibration, the temperature at a given time in which the fossils lived can be estimated. The ratios of carbon isotopes,  $^{12}\text{C}$  and  $^{13}\text{C}$ , also work in similar ways.

The limits of such a strategy is that it cannot determine which percent of  $^{16}\text{O}$  and  $^{12}\text{C}$  was incorporated into a calcite cell by  $\text{CO}_2$  respiration process rather than direct absorption from the surrounding environment. Before the 2000s, such errors were viewed as insignificant. But because later cases proved that such errors can even range between 0.3%~1%, which is a large amount of change in temperature, some foraminifera species are currently being speculated to have developed a distant oxygen exchange mechanisms with large amount of respiratory oxygen and carbon entering their calcite shells, complicating the research (Pearson,2012). Also, because oxygen and carbon uptake is varied not only by the temperature, but also by the pH of the ocean in the moment of foraminifera shell's calcifications, in some cases, slight variation of pH during the calcification process results in fluctuating data(Babila,2022, Bermis, 1998). Such offsets urge the need to find methods to determine the ocean's pH in foraminifer's calcification process.

In the 2010s, the investigation of element isotopes other than oxygen and carbon started to emerge due to advances in technology, which enabled researchers to detect minute amounts of diverse elements in foraminifera fossils. The research on isotope ratio of nitrogen( $^{14}\text{N}$ ,  $^{15}\text{N}$ ) is now at its starting point (Ren, 2009), with a focus on foraminiferal nitrogen fixation's effect in marine environments. In addition, research using boron (Babila,2022) for a better understanding of the pH of the paleo oceanic environment was also published in the 2020s, paving a new way for minimizing the errors caused by unknown pH of ancient oceans. However, elements other than oxygen and carbon generally lack accuracy than these two classical counterparts(Babila,2022), and are often used to back up the data of these two.

Therefore, using isotopes of various elements in paleoclimatology research yields the following features:

(1) Techniques of using isotope element ratio in foraminifera can result in more precise data about paleoclimate because it yields measurable data unlike the morphological studies of foraminifera; (2) The process is even more concise than the morphological study, since it only requires the dissolution of calcite and usage of isotope mass spectrometer (3) However, some foraminifera specie's unique mechanism of uptaking its own respiratory  $\text{CO}_2$  into the calcite shell often results in errors; and (4) Also, because it cannot determine the pH of the ancient sea with accuracy and cannot correct the errors in this stage, more researches are needed.

Utilization of elemental isotope is thus the most powerful to derive an numerical data about paleoclimate from foraminifera fossils, and are widely used from 1980s to 2020s with active progressions and diverse approaches. Since it still holds a limitation of not being able to

calibrate the different respiratory oxygen and carbon uptake in different foraminiferal species and pH conditions in calcifications, there is still more space for improvement of this technology.

### **Mg/Ca paleothermometry**

Investigation of the ratio between Mg/Ca elements in foraminiferal calcite first emerged in the late 1990s(Katz, 2003), and was soon used in the early 2000s(Lear,2000, Lea, 2000). Similar to previous O and C isotope ratio investigations, the analysis of the Mg/Ca element ratio is often used to identify the thermal features of the paleo-oceanic environment. It can be also used to determine the global ice volume of a certain timespan(Lear, 2000).

Mg/Ca paleothermometry follows a process almost similar to that of the utilization of radioisotopes O and C. However, it differs in that it focuses on two distinct elements, rather than the isotopes of one element. Mg and Ca proportions are used because generally as temperature increases, a constant amount of Mg is absorbed into the calcite shell. Thus, by tracking change in Mg/Ca in foraminiferal fossils, temperature change in paleo oceanic climate can be recognized.

Prior to the analysis, four things must be specified for accurate investigation. First, interspecific Mg/Ca differences should be identified because the Mg/Ca ratio at a certain temperature is often species-specific. Second, the preservation of the original Mg/Ca elements should be assessed. Third, the Mg/Ca ratio of the past sea is required. This should be determined by using another proxy or geochemical simulation. Finally, calibration was required to translate the Mg/Ca ratio into the temperature record. In most calibrations, the Mg/Ca ratio increased by approximately  $9 \pm 1\%$  per elevation in °C.(Lea,2000) A cross-section of paleothermometry data with <sup>18</sup>O isotopic data shows that the Mg/Ca data can reach the desired temperature record with accuracy(Lear,2000).

Previous research has shown the following advantages and limitations of Mg/Ca paleothermometry :

(1) It can be used in cross-checking the data of the <sup>18</sup>O isotope method since it has one of the most accurate values in determining paleoclimate; (2) However, it should be preceded by the research of the general paleoclimate in which the foraminifera lived in by other proxy tests(Lea, 2000) (3) Also, exact Mg/Ca calibration of diverse foraminifera species are not yet investigated, leading to minor errors in the researches

Based on these characteristics, it can be concluded that an analysis of the paleoclimate by foraminiferal Mg/Ca paleothermometry is a compelling use for gaining data of paleo oceanic temperature, it should be preceded by advancements in calibration and should be used with other proxy data for accuracy rather than sole performance.

### **Gene technology used in foraminiferal research**

The genetic approach to foraminifera for paleoclimatic research began very recently in the 2020s (Orsi,2020). Genetic technologies mostly aim to identify the gene evolution process that leads to certain life mechanisms or morphological features of each foraminiferal species. Although it is very difficult to extract unharmed DNAs from foraminifera fossils, genes from

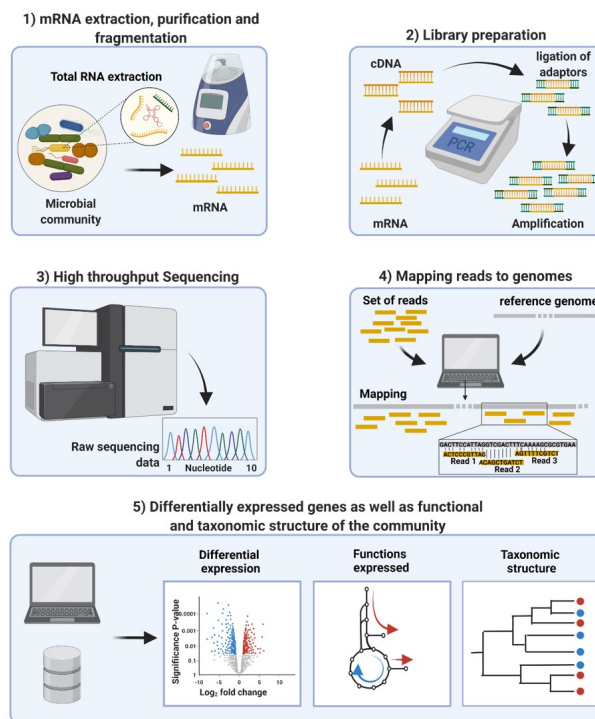
pre-foraminiferal species can be deduced from genomic research on the existing foraminifera species. Thus, research data can explain the correspondence between the evolution of foraminiferal features and certain ecological changes in deducing the cause of natural selection genes (Ujiie, 2023). The database used in foraminifera gene technology is usually the Eukaryotic Orthologous Genes (KOGSs) database. (Orsi,2020; Tatusov, 2000)

### **Metatranscriptomic research**

Metatranscriptomics is a term used for “techniques which clarify the genes that are expressed by a certain community as a whole with the use of functional annotations of expressed genes”(Pulido, 2016). Exploring gene expression variances under different microbial conditions, researchers can conclude that certain features of certain species are derived under which conditions and genes. Previous research on regulating the gene expression of certain foraminifera species populations under different conditions was able to determine the exact changing mechanism of foraminiferal shell shape by translation of certain proteins in an anoxic environment. (Orsi,2020)

In metatranscriptomic research on foraminifera, metatranscriptomes are often sequenced to an average depth of a million reads per sample(Orsi, 202), and the genes and their expression rates that contribute to specific morphological changes in shells, secretion of carbonate, or other characteristics used in research are identified under different environmental conditions. For example, by identifying that a certain gene that acts in the foraminiferal coil is expressed more frequently in a population in deeper sea basins, paleoclimatologists can conclude that foraminiferal fossils with a unique coiling nature that is likely to have been derived from such a gene would have lived in a similar environment.

Since metatranscriptomics in paleoclimatology are about analyzing genomes of existing species and making a conclusion by assuming that they had similar effects in the past, metatranscriptomic analysis is often furthered into metagenomics, which aims to explain phylogenetic tree and ancestry genomes with its descendant’s genome sequencing. Along with the genome sequencing of foraminifera under an acidic ocean environment, Yurika Ujiie’s research in 2023 proved not only the secretion of the mechanism of CaCO<sub>3</sub>, but also its evolutionary process and mechanism in collaboration with previous research that showed Precambrian ocean conditions.



**Figure 6.** General process of metatranscriptomic research (Petermann, Anke. *Metatranscriptomics - Helmholtz-Centre for Environmental Research.* [www.ufz.de/index.php?en=48524.](http://www.ufz.de/index.php?en=48524))

Research using the metatranscriptomic technique in paleoclimatic research using foraminifera proves the following characteristics of such a method:

(1) It can more logically deduce the fossilized foraminifera ecology by using the gene of its descendant (Lejzerowicz, 2016); (2) it can provide reasons for morphological change that was used for foraminifera research (Orsi, 2020), and (3) it can aid in correction of errors in pre-existing data by demonstrating changes in its certain characteristics, such as CaCO<sub>3</sub> secretion, under minute changes in microbiomes. (Ujii, 2023) (4) However, it is restricted because limits exist in that phylogenetic research cannot determine if the current species' gene plays the same role as the gene of extinct species due to gene distortion, such as common admixture between populations (Elluche, 2009).

In conclusion, metatranscriptomic research, in its current stage, is a strong tool to use the current species' genome to determine the characteristics of ancestral foraminifera and deduce changes in the environment in its evolutionary process. However, not being able to accurately suggest the genome of the foraminifera fossils in paleoclimatic research, it will be more appropriate in research that deals with foraminiferal fossils of species that went through less phylogenetic progress, and not solely by itself but as a side method of suggesting a hypothesis after isotopic data or morphological identification has been made.

## Conclusion

This comprehensive review has examined the evolution of techniques used in foraminiferal research within the context of paleoclimatic investigations spanning from the 1970s to 2023. We have outlined three primary approaches in foraminiferal research: morphological investigation, elemental ratio measurement, and genetic approaches. Each of these techniques has its unique advantages and limitations.

Morphological investigation of foraminifera faces the limitation of its time-consuming nature and the fact that the research results from the whole process is too dependable on tools, lending slight bias. Using elemental ratio can redeem the limits of morphological investigation by yielding numerical data for paleoclimatic temperatures, but there are still unexplored areas such as determination of oceanic pH and the amount of error caused by foraminifera's own respiration. Genetical approach of foraminifera can aid in estimating such uncertainties by estimating features of foraminiferal life by metatranscriptomics, yet is incomplete in that genetic research on present foraminiferal species has limitations in obtaining the exact genetic features of past foraminiferal species.

In conclusion, foraminiferal research has evolved significantly over the decades, offering a multifaceted toolkit for paleoclimatic investigations. Each technique has its strengths and limitations, and their combined use provides a comprehensive understanding of past climatic conditions. As we move forward in foraminiferal research, it is crucial to continue refining methodologies, addressing limitations, and embracing interdisciplinary approaches between different methods.

## Works Cited

- Aguiar-Pulido, Vanessa et al. "Metagenomics, Metatranscriptomics, and Metabolomics Approaches for Microbiome Analysis." *Evolutionary bioinformatics online* vol. 12, Suppl 1 5-16. 12 May. 2016, doi:10.4137/EBO.S36436
- Alvarez, Luis W., et al. "Extraterrestrial Cause for the Cretaceous-Tertiary Extinction." *Science*, vol. 208, no. 4448, American Association for the Advancement of Science, June 1980, pp. 1095–108. <https://doi.org/10.1126/science.208.4448.1095>.
- Babila, Tali L., et al. "Surface Ocean Warming and Acidification Driven by Rapid Carbon Release Precedes Paleocene-Eocene Thermal Maximum." *Science Advances*, vol. 8, no. 11, American Association for the Advancement of Science, Mar. 2022, <https://doi.org/10.1126/sciadv.abg1025>.
- Bard, Édouard, et al. "Hydrological Impact of Heinrich Events in the Subtropical Northeast Atlantic." *Science*, vol. 289, no. 5483, American Association for the Advancement of Science, Aug. 2000, pp. 1321–24. <https://doi.org/10.1126/science.289.5483.1321>.
- Bermis, Bryan et al. "Reevaluation of the Oxygen Isotopic Composition of Planktonic Foraminifera: Experimental Results and Revised Paleotemperature Equations." *Paleoceanography*, vol. 13, no. 2, American Geophysical Union, Apr. 1998, pp. 150–60. <https://doi.org/10.1029/98pa00070>.
- Clark, Peter U., et al. "The Last Glacial Maximum." *Science*, vol. 325, no. 5941, American Association for the Advancement of Science, Aug. 2009, pp. 710–14. <https://doi.org/10.1126/science.1172873>.
- Davis, Catherine V., et al. "Extensive Morphological Variability in Asexually Produced Planktic Foraminifera." *Science Advances*, vol. 6, no. 28, American Association for the Advancement of Science, July 2020, <https://doi.org/10.1126/sciadv.abb8930>.
- Elleuche, Skander, and Stefanie Pöggeler. "Evolution of Carbonic Anhydrases in Fungi." *Current Genetics*, vol. 55, no. 2, Springer Science+Business Media, Mar. 2009, pp. 211–22. <https://doi.org/10.1007/s00294-009-0238-x>.
- Erez, Jonathan. "Vital Effect on Stable-isotope Composition Seen in Foraminifera and Coral Skeletons." *Nature*, vol. 273, no. 5659, Nature Portfolio, May 1978, pp. 199–202. <https://doi.org/10.1038/273199a0>.
- Field, David B et al. "Planktonic foraminifera of the California Current reflect 20th-century warming." *Science (New York, N.Y.)* vol. 311,5757 (2006): 63-6. doi:10.1126/science.1116220
- Gehrels, W. Roland. "Determining Relative Sea-level Change From Salt-marsh Foraminifera and Plant Zones on the Coast of Maine, U.S.A." *Journal of Coastal Research*, vol. 10, no. 4, Coastal Education and Research Foundation, Oct. 1994, pp. 990–1009. [journals.fcla.edu/jcr/article/download/79472/76805](https://journals.fcla.edu/jcr/article/download/79472/76805).
- Gupta, B K, and A C Grant. "Orbitolina, a cretaceous larger foraminifer, from flemish cap: paleoceanographic implications." *Science (New York, N.Y.)* vol. 173,4000 (1971): 934-6. doi:10.1126/science.173.4000.934

- Gupta, Barun K. Sen. "Introduction to Modern Foraminifera." Springer eBooks, 1999, pp. 3–6. [https://doi.org/10.1007/0-306-48104-9\\_1](https://doi.org/10.1007/0-306-48104-9_1).
- Hallock, Pamela, and Equisha Glenn. "Larger Foraminifera: A Tool for Paleoenvironmental Analysis of Cenozoic Carbonate Depositional Facies." *PALAIOS*, vol. 1, no. 1, Society for Sedimentary Geology, Feb. 1986, p. 55. <https://doi.org/10.2307/3514459>.
- Hayward, Bruce W., et al. "Foraminifera in the World Register of Marine Species (Worms) Taxonomic Database." *Journal of Foraminiferal Research*, vol. 50, no. 3, Cushman Foundation for Foraminiferal Research, July 2020, pp. 291–300. <https://doi.org/10.2113/gsjfr.50.3.291>.
- Holbourn, Ann, et al. *Atlas of Benthic Foraminifera*. 2013, <https://doi.org/10.1002/9781118452493>.
- Introduction to IRMS. [www.nu-ins.com/products/irms/introductiontoirms](http://www.nu-ins.com/products/irms/introductiontoirms).
- Iwasaki, S., Kimoto, K., Sasaki, O. et al. "Sensitivity of Planktic Foraminiferal Test Bulk Density to Ocean Acidification." *Scientific Reports*, vol. 9, no. 1, Nature Portfolio, July 2019, <https://doi.org/10.1038/s41598-019-46041-x>.
- Jansen, J. H. Fred, et al. "A Mid-Brunhes Climatic Event: Long-Term Changes in Global Atmosphere and Ocean Circulation." *Science*, vol. 232, no. 4750, American Association for the Advancement of Science, May 1986, pp. 619–22. <https://doi.org/10.1126/science.232.4750.619>.
- Katz, Miriam, et al. "Early Cenozoic Benthic Foraminiferal Isotopes: Species Reliability and Interspecies Correction Factors." *Paleoceanography*, vol. 18, no. 2, American Geophysical Union, Apr. 2003, p. n/a. <https://doi.org/10.1029/2002pa000798>.
- Langer, Martin R., and Lukas Hottinger. "Biogeography of Selected 'Larger' Foraminifera." *Micropaleontology*, vol. 46, 2000, pp. 105–26. JSTOR, <http://www.jstor.org/stable/1486184>. Accessed 8 Oct. 2023.
- Lea, David W., et al. "Climate Impact of Late Quaternary Equatorial Pacific Sea Surface Temperature Variations." *Science*, vol. 289, no. 5485, American Association for the Advancement of Science, Sept. 2000, pp. 1719–24. <https://doi.org/10.1126/science.289.5485.1719>.
- Lear, C. H., et al. "Cenozoic Deep-Sea Temperatures and Global Ice Volumes from Mg/Ca in Benthic Foraminiferal Calcite." *Science*, vol. 287, no. 5451, 2000, pp. 269–72. JSTOR, <http://www.jstor.org/stable/3074480>. Accessed 8 Oct. 2023.
- Lejzerowicz, Franck, et al. "Identifying Active Foraminifera in the Sea of Japan Using Metatranscriptomic Approach." *Deep Sea Research Part II: Topical Studies in Oceanography*, vol. 86–87, Elsevier BV, Feb. 2013, pp. 214–20. <https://doi.org/10.1016/j.dsr2.2012.08.008>.
- Micropaleontology Lab - GEOMAR - Helmholtz-Zentrum Für Ozeanforschung Kiel. [www.geomar.de/en/research/fb1/fb1-p-oz/infrastructure/micropaleontology-lab](http://www.geomar.de/en/research/fb1/fb1-p-oz/infrastructure/micropaleontology-lab).
- Murray, John W. *Ecology and Applications of Benthic Foraminifera*. 2006, <https://doi.org/10.1017/cbo9780511535529>.



- Oron, Shai et al. "Depth related adaptations in symbiont bearing benthic foraminifera: New insights from a field experiment on *Operculina ammonoides*." *Scientific reports* vol. 8, 1 9560. 22 June. 2018, doi:10.1038/s41598-018-27838-8
- Orsi, W.D et al. "Anaerobic Metabolism of Foraminifera Thriving Below the Seafloor." *The ISME Journal*, vol. 14, no. 10, Nature Portfolio, July 2020, pp. 2580–94. <https://doi.org/10.1038/s41396-020-0708-1>.
- Pawlowski, Jan, et al. "New Supraordinal Classification of Foraminifera: Molecules Meet Morphology." *Marine Micropaleontology*, vol. 100, Elsevier BV, Apr. 2013, pp. 1–10. <https://doi.org/10.1016/j.marmicro.2013.04.002>.
- Pearson, Paul Nicholas, and L. Moore Penny. "Coiling Directions in the Planktonic Foraminifera Pulleniatina: A Complex Eco-evolutionary Dynamic Spanning Millions of Years." *PLOS ONE*, vol. 16, no. 4, Public Library of Science, Apr. 2021, p. e0249113. <https://doi.org/10.1371/journal.pone.0249113>.
- Petermann, Anke. Metatranscriptomics - Helmholtz-Centre for Environmental Research. [www.ufz.de/index.php?en=48524](http://www.ufz.de/index.php?en=48524).
- Ren, Haojia, et al. "Foraminiferal Isotope Evidence of Reduced Nitrogen Fixation in the Ice Age Atlantic Ocean." *Science*, vol. 323, no. 5911, American Association for the Advancement of Science, Jan. 2009, pp. 244–48. <https://doi.org/10.1126/science.1165787>.
- Sanghun Shin "A Method for Determining the Coiling Ratio and Classifying Species of Fossil Planktonic Foraminifera Using Digital Image Analysis" *The Journal of The Korean Earth Science Society* 25.8 pp.799-815 (2004) : 799.
- Scott, David, and Franco S. Medioli. "Vertical Zonations of Marsh Foraminifera as Accurate Indicators of Former Sea-levels." *Nature*, vol. 272, no. 5653, Nature Portfolio, Apr. 1978, pp. 528–31. <https://doi.org/10.1038/272528a0>.
- Tatusov, Roman L. "The COG Database: A Tool for Genome-scale Analysis of Protein Functions and Evolution." *Nucleic Acids Research*, vol. 28, no. 1, Oxford UP, Jan. 2000, pp. 33–36. <https://doi.org/10.1093/nar/28.1.33>.
- Thayer, Charles W. "Biological Bulldozers and the Evolution of Marine Benthic Communities." *Science*, vol. 203, no. 4379, American Association for the Advancement of Science, Feb. 1979, pp. 458–61. <https://doi.org/10.1126/science.203.4379.458>.
- Ujiié, Yurika et al. "Unique evolution of foraminiferal calcification to survive global changes." *Science advances* vol. 9,25 (2023): eadd3584. doi:10.1126/sciadv.add3584
- Via, M et al. "Recent advances of genetic ancestry testing in biomedical research and direct to consumer testing." *Clinical genetics* vol. 76,3 (2009): 225-35. doi:10.1111/j.1399-0004.2009.01263.x
- Zachos, James C., et al. "Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present." *Science*, vol. 292, no. 5517, American Association for the Advancement of Science, Apr. 2001, pp. 686–93. <https://doi.org/10.1126/science.1059412>. [Original source: <https://studycrumb.com/alphabetizer>]

# **Impact of Calorie Labeling on Eating Behaviors and Eating Disorder Symptomatology**

## **By Ellie Lee**

### **Abstract**

With the increase in unhealthy eating behaviors and eating disorders, calorie labels on menus and food labels can have an influential role in improving—or harming—consumers’ eating behaviors. This paper evaluates existing research to examine the associations between calorie labeling on food labels or menus and eating behaviors, including disordered eating. Research shows that excessive use of calorie information and calorie tracking can contribute to eating disorder symptomatology. Additionally, how calorie content is presented on labels can affect the relationship between calorie labeling and disordered eating. Despite potential negative effects, calorie information can also promote healthier eating behaviors, such as avoiding high-calorie options.

### **Introduction**

Unhealthy eating behaviors come in many forms from overconsumption to other eating disorders. Overconsumption of calories, sodium, fats, and sugars has become increasingly prevalent with the rise of fast food industries and highly processed foods, and such eating behaviors have been shown to contribute to the rise of obesity and noncommunicable diseases like type 2 diabetes and high blood pressure (Popkin and Ng e13366). Characterized by disturbed eating food-related behavior and mental distress, eating disorders have become increasingly prevalent, especially among adolescents and 15–19-year-old girls (Smink et al. 406-414; Smith et al. 63-67).

Such habits are potentially influenced by calorie information on food labels and menus. In the United States, calorie information has been included in the Nutrition Facts panel since nutrition labeling was mandated in 1993 (Committee on Examination of Front-of-Package Nutrition Ratings Systems and Symbols et al.). An update in 2016 from the Food and Drug Administration requires calorie information to be presented in a larger type (“Changes to the Nutrition Facts Label”). Furthermore, in the United States, the federal Patient Protection and Affordable Care Act was signed in 2010 and required any restaurant chains with twenty or more stores throughout the nation to provide calorie information on menus (Peregrin 1144-1146, as cited in Wei and Miao 106-117). Although calorie information has been shown to decrease calorie consumption and increase consumer awareness about the caloric content of foods, this isn’t always beneficial, especially regarding eating disorder symptomatology (Christoph and An 187-203; Larson et al. 399-408; Dumanovsky et al.; Gerend 84-86; Haynos and Roberto 275-283). Furthermore, calorie-tracking apps require and instill constant calorie counting and continuous utilization of calorie labels and information, which can further increase eating disorder symptomatology (McCaig et al. 404-411; Levinson et al. 14-16; Hahn, Hazzard et al. 106967).

Therefore, emphasis on calorie labels and calorie counting can have long-term consequences like eating disorders. Anorexia nervosa (AN) is characterized by severely restricting nutritional intake due to an intense fear of gaining weight or being fat. Bulimia nervosa (BN) includes alternating between eating only low-calorie foods and binge eating, eating a large amount of food in a short period, of high-calorie foods. The guilt of consumption and sense of loss of control often leads to “compensatory behaviors” like fasting, vomiting, or compulsive exercise. Binge eating disorders (BED) also include binge eating like bulimia, but do not include regulatory compensatory behaviors. Such disrupted nutritional intake can have lifelong consequences, including being fatal (“Psychiatry.org - What Are Eating Disorders?”). Lifetime prevalence rates range from 0.5% to 1.0% for AN, 1% to 3% for BN, and 2% to 2.5% for BED (American Psychiatric Association; Hudson et al. 348-358; Smink et al. 406-414; as cited in Smith et al. 63-67).

With the increase in unhealthy eating behaviors and eating disorders, calorie labels on menus and calorie information on food labels can be an influential tool in affecting consumers’ eating behaviors. This paper examines the impact of calorie information on food labels or menus on eating behaviors, including overconsumption and disordered eating, and gives suggestions on how this can be improved.

### **How Food Labels Impact Eating Behaviors**

While this paper focuses specifically on the calorie information on food labels, exposure to food labels as a whole can also alter consumers eating behaviors, both positively and negatively – reducing calories overconsumption but impacting eating behaviors detrimentally.

Researchers found that the use of labels significantly lowered fat intake by approximately 6% when demographic, psychosocial, and behavioral variables were controlled (Neuhouser et al. 45-53). In addition, food labels can facilitate weight control. A study that assessed 1,817 young adults revealed that increased use of nutrition facts was associated with a 23% increased likelihood of engaging in healthy weight control among women and a 27% increased likelihood of engaging in healthy weight control among men (Christoph and An 187-203), exemplifying the potential positive effect of food labels across genders. Nutrition labels can also promote healthy weight control without leading to eating disorder symptoms. With their potential to decrease calories and fat intake and aid general weight management, food labels can help address widespread health concerns like obesity.

However, labeling techniques that seem to have healthier sentiments like “organic,” “low fat,” or “sugar-free” can be misinterpreted and have negative effects on consumer eating behaviors. Studies have shown that labeling in such a way has recursive effects on quantity and volume of consumption. In three studies by Wansink and Chandon assessing the effect of low-fat labels, results showed that all consumers, particularly those who are overweight, overate snacks labeled “low-fat.” In this case, low-fat labels altered perceptions about the amount appropriate for participants to eat and decreased guilt about eating the product (Wansink and Chandon 605-617). Labels like “low fat” are often highlighted by manufacturers to demonstrate the

potential health advantages of their products. Yet such attempts to encourage the use of healthier products can be misinterpreted and cause consumers to overestimate the healthiness of these products. This overestimate results in overconsumption of these foods, which may still result in negatively impact their eating behaviors.

Furthermore, Christoph et al. found that women were 17% more likely to binge eat and 10% more likely to engage in other unhealthy weight control behaviors with greater use of nutrition labels, while men were 17% more likely to engage in unhealthy weight control (Christoph et al. 267-274). The evidence portrays the possibility of food labels contributing to eating disorder symptomatology and also potential gender differences in such negative effects.

However, this section portrays evidence assessing the impact of exposure to food labels in general but does not assess a particular section of the label like calorie information.

### **Individual Differences**

Although food labels can impact eating behaviors, individual differences in eating behaviors can also influence the use of and the potential effects of food labels.

Factors of a person's eating behaviors like nutrient intake, avoidance of specific ingredients, beliefs about certain foods, and weight consciousness, play a crucial role in determining the type of nutritional information that influences their food decisions.

One key nutrient that influences buying patterns is fat content. Consumers differ in their buying behavior depending on their fat-related choices. For example, one set of researchers found that individuals who consume a high percentage of calories from fat are less likely to look at fat information on food labels (Lin and Lee 17-37). Contrastingly, a study focused on those who value a low-fat diet found that participants attempting to consume a low-fat diet were strongly likely to use food labels (Neuhouser et al. 45-53). This is further supported by a study done by Kreuter et al. on 885 adults demonstrating that those eating lower-fat diets were 25% more likely to use labels when purchasing food, as compared to those eating higher-fat diets (Kreuter et al. 277-283).

Furthermore, those more likely to prioritize healthy eating will utilize food labels as a valuable source of information to reiterate their eating behaviors. Kreuter et al. found that individuals who prefer diets higher in fruits, vegetables, and fiber reported higher use of food labels (Kreuter et al. 277-283). Therefore, preferences and consumption habits of certain nutrients can cause individuals to look at the correlating nutritional information on packaging.

### **Calorie Counting and Eating Disorder Symptomatology**

The use of calorie information on food labels has popularized calorie counting, a practice often involving tracking apps that allow users to log the number of calories in every serving of food consumed per day. Calorie counting is an extensive and constant process that makes participants aware of their caloric and overall food intake, and this constant measurement can have both negative and positive impacts on one's diet and health.

Calorie counting has been shown to have a negative impact on some consumers' eating behaviors, specifically regarding eating disorder symptoms. According to a study done on 493 college students, those who tracked calories reported higher levels of eating concerns and dietary restraint (Simpson and Mazzeo 89-92). Regarding calorie labeling in restaurants, using calorie labels on menus to limit caloric consumption was associated with more weight-related concerns, dieting, and unhealthy weight-control behaviors among both women and men (Larson et al. 399-408). The evidence demonstrates that exposure to and tracking calorie information displayed on food labels or restaurant menus can contribute to eating disorder symptomatology including weight-related concerns, unhealthy weight control, and negative body weight perception.

This association is partly influenced by individuals' motives for calorie tracking. According to a study of 1357 current or previous users of a calorie-tracking app, those who utilize calorie tracking to control their weight were more likely to report that the app contributed to eating disorder symptoms including food preoccupation, food anxiety, and purging behaviors than those calorie tracking for other health reasons like disease prevention (Messer et al. 101568). Furthermore, a study of 902 college students demonstrated that those with higher weight, more frequent self-weighing and calorie counting, and lower intuitive eating scores predicted increased eating disorder severity (Romano et al. 841-848). Therefore, individuals with a greater prevalence of calorie counting for weight control reasons or calorie counting more frequently, both of which contribute to eating disorder symptomatology.

One specific calorie-counting app that has been studied is *MyFitnessPal*. The main functions of *MyFitnessPal* are for users to set goals concerning weight, calorie intake, and macronutrient intake, and assess their goal progress by estimating and tracking their calorie intake and nutrient intake (e.g., consulting a food database, scanning barcodes, creating their entries for foods among other weight control procedures ("Free Calorie Counter, Diet & Exercise Journal" as cited in McCaig et al. 404-411)). According to a qualitative analysis of 1,695 comments regarding the app on three eating disorder-related forums, people with high eating disorder symptomatology are likely to engage with *MyFitnessPal* (McCaig et al. 404-411). This is further supported by a study done on 105 individuals diagnosed with eating disorders by Levinson et al. in 2017. Out of these participants, 75% of the individuals used *MyFitnessPal*, and of these users, 73% believed that the app contributed to their eating disorders, and such perceptions further correlated with eating disorder symptoms (Levinson et al. 14-16). The study demonstrates that *MyFitnessPal* is commonly used among those with eating disorders and can elevate eating disorder symptoms.

Another study found that the use of weight-related self-monitoring (WRS) apps including both physical activity-focused and dietary-focused, in general, is associated with a greater adjusted prevalence of disordered weight-control behaviors like fasting and purging in both men and women. Furthermore, users who engaged in WRS also had a higher adjusted prevalence of common weight control behaviors like exercising and changing eating behaviors (Hahn, Hazzard et al. 106967). This demonstrates that there is a significant relationship between

WRSM and disordered weight control, and this relationship can elevate non-disordered weight control as well.

However, one study done on 200 undergraduate women who did not participate in dietary self-monitoring in the past year and are at low risk of an eating disorder showed that using *MyFitnessPal* for 1 month did not increase eating disorder risk, impact other aspects of mental health, or alter health behaviors including dietary intake for these women (Hahn, Kaciroti et al. 2377-2388). This demonstrates that the negative effects of calorie counting apps may be greater for those with existing eating disorder symptomatology but not for those who do not have a risk for eating disorders.

Although researchers have found that calorie counting can negatively impact both women and men, the effects of calorie tracking slightly differ by gender. A study on 10,010 undergraduate and graduate students done by Hahn, Bauer et al. in 2021 observed that women who weighed themselves regularly, knew nutrition facts of the foods consumed, or counted calories all exhibited increased eating disorder symptomatology. In comparison, men only displayed this symptomatology when they did all the listed actions together (Hahn, Bauer et al. 595-605). The evidence suggests that women are more susceptible to eating disorder symptomatology if they partake in any form of WRSM.

### **Positive Effect of Calorie Information on Eating Behaviors**

While constant calorie counting can negatively impact eating disorder symptoms, the availability of calorie information on food labels and menus can still positively impact consumers' food choices, leading to a reduction in the number of calories consumed and portion sizes. While this may not be ideal and healthy for everyone, it can be beneficial for those trying to cut down calories or avoid overly high-caloric intakes. A meta-analysis of studies demonstrated a 36 kcal decrease, a small portion of the standard 2,000-calorie diet but still a measurable difference, with the presence of food labels (Christoph and An 187-203). Therefore, exposure to food labels may benefit individuals who aim to decrease their calorie consumption.

An experiment on 788 men and 1042 women demonstrated that 50.1% of participants who used the calorie information at a restaurant did so to avoid high-calorie menu items while 20.2% did so to decide on a smaller portion (Larson et al. 399-408). This demonstrates that some consumers' are viewing calorie information already aware of their desires to reduce caloric intake.

Calorie labels can also encourage consumers to consume fewer calories. When the meal selection of 100 college students was observed, results showed that students ordered significantly fewer calories when calorie information was posted than not posted (Stran et al. 215-223). A different study among female students at a university restaurant demonstrated that female students who were given food menus with calorie labeling consumed 59 fewer calories than students given menus without calorie labeling (Al-Otaibi et al. 1-9).

The positive effect of calorie labeling can be especially useful in fast food restaurants where there are many high-calorie food options. In a study conducted on 168 randomly selected

locations of the top 11 fast food chains in New York City, researchers surveyed customers before (2007) and after (2009) the implementation of calorie labels on menus. Although there was no significant change in mean calories purchased across the entire sample, specific chains, such as McDonald's and KFC, showed significant reductions in mean calories purchased after labeling was introduced. For McDonald's, mean calories decreased from 829 to 785 kcal, and for KFC, they decreased from 927 to 868 kcal (Dumanovsky et al.). In a different study of college women, women exposed to calorie labels in fast-food restaurants consumed 146 fewer calories per meal than women who did not receive calorie information, an amount the author analyzes would translate into a reduction of 7,592 calories annually if women were to eat fast food once a week (Gerend 84-86).

However, it is important to note that the possible positive effects of calorie labels can be modified by gender. An experiment evaluating the effects of calorie information on college students' fast food choices demonstrated female students chose lower-calorie meals and items when calorie information was available while male students' food choices were unaffected (Gerend 84-86). This may be because women are more conscious about their weight and caloric intake, possibly due to societal pressures on a woman's body weight and shape (Calogero et al. 259-298; Groesz et al. 1-16; McKinley 113-123). Meanwhile, men may desire to “bulk” and meet the societal pressures of men's body weight and shape, implying that the differences may not be due to physiological differences between genders but more gender social pressures (Cafri et al. 421; McCreary and Sasse 297-304; Thompson and Cafri).

Furthermore, it is crucial to note that generalizing fewer calories ordered and consumed as a positive effect for all consumers can be misleading. When Haynos and Roberto observed the effect of restaurant menu calorie labeling on females with disordered eating in 2017, there was not a significant effect overall across the different eating disorders. However, when results were broken down by different types of eating disorders, Haynos and Roberto found that participants with anorexia nervosa or bulimia nervosa ordered significantly fewer ( $p < .001$ ) calories with calorie labels while participants with binge-eating disorder ordered significantly more ( $p = .001$ ) calories with calorie labels (Haynos and Roberto 275-283). For individuals with anorexia nervosa who avoid consuming calories to become thin or with bulimia nervosa and purge to remove calories consumed from their bodies, choosing fewer calories could emphasize patterns that determine their symptomatology and heighten their eating disorders. For individuals with binge-eating disorders who consume large amounts of food and correlatively large amounts of calories in a short period of time, choosing more calories could heighten their binge episodes. Therefore, while food labels can reduce caloric intake, this may not be a health benefit for all individuals.

How Food Labels can be Improved to Influence Consumer Eating Behaviors

An overemphasis on the caloric content on food labels can oversimplify consumers' understanding of "healthful" products into a single number (Lucan and DiNicolantonio 571-581). This may be partly attributed to the way calorie information is displayed: compared to information regarding more specific nutrients, the number of calories is written in bigger font ("Changes to the Nutrition Facts Label"). Such emphasis on calories may influence the relationship between calorie counting and eating disorder symptomatology

Furthermore, certain product packages present nutritional information based on extremely small serving sizes. This can lead to confusion as consumers need to perform calculations to apply the provided numbers and percentages to the entire package. Additionally, serving sizes reported on packaging lack regulation, with some manufacturers indicating quantities (e.g., number of chips or pieces of chocolate) while others provide measurements in grams. The use of grams can lead to a further lack of clarity as grams may not be easily quantifiable for consumers. Moreover, if consumers do not consider the serving size, the provided nutrition information can be highly deceptive.

Although the serving size is bolded on the nutrition facts label, paying attention to this detail may not be intuitive for all. When presented with lower calorie counts per serving (even if one serving size is 10 grams and another is 100 grams), consumers tend to favor the product with the lower caloric value, overlooking the misleading nature of this representation (Mohr et al. 59-75). Instead, nutrition labels can highlight the number of servings to encourage consideration of the quantity the number of calories truly accounts for or, even better, make the serving sizes simple in nature. Making sample sizes the whole package or easily quantifiable portions like  $\frac{1}{2}$  the whole bag (instead of unusual fractions like  $\frac{2}{3}$ ) would give consumers a better idea of the nutritional contents of the products.

Furthermore, an experiment exploring color's influence on perceived product healthiness revealed that consumers deemed a candy as healthier when presented in green rather than red and white, even when both candies had identical calorie contents (Schuldt 814-821). This illustrates the potential for green color to enhance perceived healthiness, benefiting food production companies but potentially misleading consumers.

Additionally, a review of consumer and industry responses to nutrition labeling in the global south revealed a preference for label formats incorporating graphics or symbols. Notably, a study investigating calorie intake in restaurants found that while numeric calorie labels had limited impact on consumers already more knowledgeable about health and nutrition, symbolic calorie labels significantly reduced caloric intake across all participant categories, including those most health-conscious (Ellison et al. 1-9).

An imperative stride toward enhancing the utility of food labels and effecting positive changes in consumer choices revolves around the enhancement of nutritional education. Whether disseminated by providers, integrated into school curricula, or disseminated as public health insights, acquiring the skills to decipher the intricate components of a food label can profoundly elevate and refine consumer interpretations of the provided nutritional information. Beyond this, consumers stand to gain immensely from comprehensive nutritional instruction encompassing



diverse nutrient categories, the wellness advantages of optimal nutrition, and the cultivation of healthier eating behaviors.

## **Conclusion**

Food labels can influence eating behaviors both positively and negatively, and individual differences in dietary preferences and habits can further shape how consumers interact with these labels. More specifically, calorie information on food labels and menus can increase consumer awareness about the caloric components of items. This increased awareness can both increase eating disorder symptomology and decrease overconsumption. Calorie counting, whether through labels, menus, or apps, can worsen eating disorder symptoms, particularly for those tracking calories for weight control. Apps like *MyFitnessPal* are associated with heightened symptoms, especially in individuals with existing risk.

Although calorie counting can negatively impact eating disorder symptoms, the presence of calorie information on food labels can lead to reduced calorie consumption and portion sizes, benefiting those aiming to cut down on calories. However, the impact of calorie labels can vary based on factors such as gender, eating disorder tendencies, and specific eating behaviors, suggesting that while they can be beneficial, the effects may not uniformly apply to all individuals.

Outside of standard forms of calorie counting and tracking applications, there may be better ways to restrict one's food intake with decreased eating disorder connotations, including intermittent fasting and intuitive eating. Intermittent fasting is characterized by a set fasting time period throughout the day, commonly restricting eating from early nighttime to the morning after. One example is a 16/8 intermittent fasting pattern with a 16-hour period of fasting and 8-hour periods of eating (Volpe 34-36). Intermittent fasting has been shown to have health benefits including not only weight loss but also improved metabolism which can prompt long-term weight loss or weight maintenance (Patterson and Sears 371-393). Intuitive eating can be defined as eating when hungry, not eating when full, but not necessarily restricting the type of food consumed. Intuitive eating has been shown to decrease BMI and has become an increasingly popular weight control method as it can lead to better psychological health compared to much more restrictive diets (Van Dyke and Drinkwater 1757-1766). Therefore, due to the potential negative impact of calorie counting on eating disorder symptomatology, consumers may benefit from utilizing and viewing nutritional information and food intake more holistically to ensure a healthy relationship with food consumption.

Furthermore, food labels highlighting calorie content can simplify the perception of healthy products, which may contribute to the relationship between calorie labeling and eating disorders. Additionally, confusing serving sizes and the potential influence of packaging colors can further mislead consumers' evaluation of the calories of a product. Therefore, policymakers should consider the impact of calorie labeling on eating disorder symptomatology and consumers' eating behaviors to better assess how to display nutritional information.

## Works Cited

- Al-Otaibi, Hala, et al. "Is Calorie Labeling on Menus Related to Weight Disturbances among Females in Saudi Arabia?" *Journal of Nutrition and Metabolism*, vol. 2021, 3(2021): 1–9
- American Psychiatric Association, D. S. M. T. F., and American Psychiatric Association. *Diagnostic and statistical manual of mental disorders: DSM-5*. Vol. 5. No. 5. Washington, DC: American psychiatric association, 2013.
- Cafri, Guy, Yuko Yamamiya, Michael Brannick, and J. Kevin Thompson. "The influence of sociocultural factors on body image: A meta-analysis." *Clinical Psychology: science and practice* 12.4 (2005): 421.
- Calogero, Rachel M., Michael Boroughs, and J. Kevin Thompson. "The impact of Western beauty ideals on the lives of women: A sociocultural perspective." *The body beautiful: Evolutionary and sociocultural perspectives*. London: Palgrave Macmillan UK, (2007): 259-298.
- Christoph, Mary J, et al. "Nutrition Facts Use in Relation to Eating Behaviors and Healthy and Unhealthy Weight Control Behaviors." *Journal of Nutrition Education and Behavior*, vol. 50, no. 3 (2018): 267-274.
- Christoph, Mary J., and Ruopeng An. "Effect of nutrition labels on dietary quality among college students: a systematic review and meta-analysis." *Nutrition reviews* 76.3 (2018): 187-203.
- Committee on Examination of Front-of-Package Nutrition Ratings Systems and Symbols, et al. *Examination of Front-of-Package Nutrition Rating Systems and Symbols: Phase I Report*. Edited by Ellen A. Wartella, et al., National Academies Press, 2011
- Dumanovsky, Tamara, Christina Y. Huang, Cathy A. Nonas, Thomas D. Matte, Mary T. Bassett, and Lynn D. Silver. "Changes in energy content of lunchtime purchases from fast food restaurants after introduction of calorie labelling: cross sectional customer surveys." *Bmj* 343 (2011).
- Ellison, Brenna, Jayson L. Lusk, and David Davis. "Looking at the label and beyond: the effects of calorie labels, health consciousness, and demographics on caloric intake in restaurants." *International Journal of Behavioral Nutrition and Physical Activity* 10.1 (2013): 1-9.
- Gerend, Mary A. "Does calorie information promote lower calorie fast food choices among college students?." *Journal of Adolescent Health* 44.1 (2009): 84-86.
- Groesz, Lisa M., et al. "The effect of experimental presentation of thin media images on body satisfaction: A meta-analytic review." *International Journal of Eating Disorders*, vol. 31, no. 1 (2001): 1–16.
- Hahn, Samantha L., Niko Kaciroti, Daniel Eisenberg, Heidi M. Weeks, Katherine W. Bauer, and Kendrin R. Sonneville. "Introducing dietary self-monitoring to undergraduate women via a calorie counting app has no effect on mental health or health behaviors: results from a randomized controlled trial." *Journal of the Academy of Nutrition and Dietetics* 121.12 (2021): 2377-2388.

- Hahn, Samantha L., Katherine W. Bauer, Niko Kaciroti, Daniel Eisenberg, Sarah K. Lipson, and Kendrin R. Sonneville. "Relationships between patterns of weight-related self-monitoring and eating disorder symptomology among undergraduate and graduate students." *International Journal of Eating Disorders* 54.4 (2021): 595-605.
- Hahn, Samantha L., Vivienne M. Hazzard, Katie A. Loth, Nicole Larson, Laura Klein, and Dianne Neumark-Sztainer. "Using apps to self-monitor diet and physical activity is linked to greater use of disordered eating behaviors among emerging adults." *Preventive medicine* 155 (2022): 106967.
- Haynos, Ann F., and Christina A. Roberto. "The effects of restaurant menu calorie labeling on hypothetical meal choices of females with disordered eating." *International Journal of Eating Disorders* 50.3 (2017): 275-283.
- Hudson, James I., et al. "The prevalence and correlates of eating disorders in the National Comorbidity Survey Replication." *Biological psychiatry* 61.3 (2007): 348-358.
- Kreuter, Matthew W., et al. "Do nutrition label readers eat healthier diets? Behavioral correlates of adults' use of food labels." *American journal of preventive medicine* 13.4 (1997): 277-283.
- Larson, Nicole, et al. "Calorie labels on the restaurant menu: is the use of weight-control behaviors related to ordering decisions?." *Journal of the Academy of Nutrition and Dietetics* 118.3 (2018): 399-408.
- Levinson, Cheri A., et al. "My Fitness Pal Calorie Tracker Usage in the Eating Disorders." *Eating Behaviors*, vol. 27 (2017): 14-16.
- Lin, Chung-Tung Jordan, and Jonq-Ying Lee. "Who uses food label information: A case study of dietary fat." *Journal of Food Products Marketing* 10.4 (2004): 17-37.
- Lucan, Sean C., and James J. DiNicolantonio. "How calorie-focused thinking about obesity and related diseases may mislead and harm public health. An alternative." *Public Health Nutrition* 18.4 (2015): 571-581.
- McCaig, Duncan, et al. "Engagement with MyFitnessPal in eating disorders: Qualitative insights from online forums." *International Journal of Eating Disorders* 53.3 (2020): 404-411.
- McCreary, Donald R., and Doris K. Sasse. "An exploration of the drive for muscularity in adolescent boys and girls." *Journal of American college health* 48.6 (2000): 297-304.
- McKinley, Nita Mary. "Gender differences in undergraduates' body esteem: The mediating effect of objectified body consciousness and actual/ideal weight discrepancy." *Sex roles* 39.1-2 (1998): 113-123.
- Messer, Mariel, et al. "Using an app to count calories: Motives, perceptions, and connections to thinness-and muscularity-oriented disordered eating." *Eating behaviors* 43 (2021): 101568.
- Mohr, Gina S., Donald R. Lichtenstein, and Chris Janiszewski. "The effect of marketer-suggested serving size on consumer responses: the unintended consequences of consumer attention to calorie information." *Journal of Marketing* 76.1 (2012): 59-75.

- Neuhouser, Marian L., Alan R. Kristal, and Ruth E. Patterson. "Use of food nutrition labels is associated with lower fat intake." *Journal of the American dietetic Association* 99.1 (1999): 45-53.
- Patterson, Ruth E., and Dorothy D. Sears. "Metabolic effects of intermittent fasting." *Annual review of nutrition* 37 (2017): 371-393.
- Peregrin, Tony. "Next on the menu: Labeling law could mean new career opportunities for RDs." *Journal of the American Dietetic Association* 8.110 (2010): 1144-1146.
- Popkin, Barry M., and Shu Wen Ng. "The nutrition transition to a stage of high obesity and noncommunicable disease prevalence dominated by ultra-processed foods is not inevitable." *Obesity Reviews* 23.1 (2022): e13366.
- Romano, Kelly A., et al. "Helpful or harmful? The comparative value of self-weighing and calorie counting versus intuitive eating on the eating disorder symptomology of college students." *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity* 23 (2018): 841-848.
- Schuldt, Jonathon P. "Does green mean healthy? Nutrition label color affects perceptions of healthfulness." *Health communication* 28.8 (2013): 814-821.
- Simpson, Courtney C., and Suzanne E. Mazzeo. "Calorie counting and fitness tracking technology: Associations with eating disorder symptomatology." *Eating behaviors* 26 (2017): 89-92.
- Smink, Frédérique RE, Daphne Van Hoeken, and Hans W. Hoek. "Epidemiology of eating disorders: incidence, prevalence and mortality rates." *Current psychiatry reports* 14.4 (2012): 406-414.
- Smith, April R., Kelly L. Zuromski, and Dorian R. Dodd. "Eating disorders and suicidality: what we know, what we don't know, and suggestions for future research." *Current opinion in psychology* 22 (2018): 63-67.
- Stran, Kimberly A., et al. "College students' intentions to use calorie information on a restaurant menu: Application of the Theory of Planned Behavior." *American Journal of Health Education* 47.4 (2016): 215-223.
- Thompson, J., and Guy Ed Cafri. *The muscular ideal: Psychological, social, and medical perspectives*. American Psychological Association, 2007.
- Van Dyke, Nina, and Eric J. Drinkwater. "Review article relationships between intuitive eating and health indicators: literature review." *Public health nutrition* 17.8 (2014): 1757-1766.
- Volpe, Stella Lucia. "Intermittent Fasting—What Is It and Does It Work?." *ACSM's Health & Fitness Journal* 23.1 (2019): 34-36.
- Wansink, Brian, and Pierre Chandon. "Can "low-fat" nutrition labels lead to obesity?." *Journal of marketing research* 43.4 (2006): 605-617.
- Wei, Wei, and Li Miao. "Effects of calorie information disclosure on consumers' food choices at restaurants." *International Journal of Hospitality Management* 33 (2013): 106-117.

- “Changes to the Nutrition Facts Label.” FDA, 7 March 2022,  
<https://www.fda.gov/food/food-labeling-nutrition/changes-nutrition-facts-label>. Accessed 4 September 2023.
- “Free Calorie Counter, Diet & Exercise Journal.” MyFitnessPal, Under Armour Inc., 2019,  
[https://www.myfitnesspal.com/welcome/learn\\_more](https://www.myfitnesspal.com/welcome/learn_more). Accessed 4 September 2023.
- “Psychiatry.org - What are Eating Disorders?” American Psychiatric Association,  
<https://www.psychiatry.org/patients-families/eating-disorders/what-are-eating-disorders>.  
Accessed 4 September 2023.

# Potential Areas of Improvement for the Environmental Impact of Electric Vehicles By Troy Kim and Aidan Shin

## Abstract

Ca recently proposed the end of the production of internal combustion engine vehicles in California by the year 2035. This may mark the beginning of a nationwide trend to attempt to eliminate or reduce carbon emissions, but what are the actual effects of increasing electric vehicle (EV) usage on overall pollution? In an era of ever-expanding world-wide vehicle usage and electric vehicle production, microplastic pollution may actually increase since electrical vehicles weigh significantly more due to their heavy battery load. This increased weight produces more tire wear (through a rolling resistance and torque mechanism) and an increasing rate of road destruction. There are environmental and health costs associated with this rapid expansion of microplastic pollution. Not only do electric vehicles have a shorter lifespan than traditional combustion vehicles, but there are several unseen costs associated with EV battery replacement, recharging infrastructure, and road repair. Future recommendations in this area include more efficient and lighter batteries, the incorporation of other vehicle technologies, and government regulations.

Keywords: microplastics, solid-state battery, electric vehicles, criteria pollutants, rolling resistance, carbon dioxide

## 1. Introduction

Reducing the use of combustion-engined vehicles has become a prevalent topic in today's world. The goal of ending dependence on combustion vehicles by 2035, as proposed by California Governor Gavin Newsom in 2020, is widely seen as commendable. Electric vehicles (EVs) have emerged as a promising replacement for traditional automobiles, with their advanced technology, sleek designs, low operating costs, and convenience. Many view them as a solution to reduce emissions, climate change concerns, and pollution. However, the reality of the EV's environmental impact is more complex.

Electric vehicles appear to be an environmentally friendly choice, as they rely solely on electricity, eliminating tailpipe emissions. This shift is considered revolutionary in terms of reducing the environmental impact of daily commuting. EVs also offer convenience, with the option to recharge at home through a wall charger at a lower cost than traditional refueling. The absence of a combustion engine provides a smoother and more refined driving experience, often exceeding expectations.

Despite these advantages, a significant issue arises weight. While electric motors are lighter than internal combustion engines, the battery packs that power EVs contribute to their overall weight, making them heavier than their gasoline-powered counterparts. This additional weight places strain on tires and the road surface. As tires wear out, they release microscopic plastic particles known as microplastics, which are invisible to the naked eye. These particles can

infiltrate our lungs, ecosystems, and atmosphere, posing serious environmental and health risks. Additionally, addressing this pollution issue requires substantial financial resources, which are expected to grow over time.

Microplastic pollution has been a concern since the invention of cars, as all vehicles emit microplastics from their tires as they wear down over time. However, with the rising popularity of electric and conventional vehicles, microplastics have become an even more significant issue. In 2022, electric cars constituted 5.6% of all car sales, up from 3.1% in 2021, and this trend is expected to continue. Increased vehicle usage in the United States, with a collective 3.2 trillion miles driven, has led to road degradation, impacting the economy as resource demand and prices rise.

Moreover, the production of electric car batteries necessitates costly and environmentally hazardous resources. The public's enthusiastic support for electric cars, driven by marketing campaigns portraying them as a comprehensive solution, has led to a narrow focus on this technology. However, a singular solution can create new problems, and concentrating solely on electric vehicles may exacerbate issues like microplastics and resource development, compounding existing environmental challenges.

Road degradation exacerbates pollution by transporting harmful particles through runoff and the air. "Road runoff" carries particles into the soil and water supply, causing pollution. Smaller, airborne microplastic particles, invisible to the human eye, can be carried by the wind, infiltrating ecosystems and posing health risks. In addition, road degradation increases maintenance costs, further straining resources.

Microplastic emissions pose a significant environmental threat due to their size and weight. These particles, ranging from 10 nm to several hundred  $\mu\text{m}$  in diameter, can infiltrate organisms and respiratory pathways, limiting oxygen exchange in the lungs. The weight of microplastic particles influences their spread through emissions and runoff, with potentially adverse effects on organisms and the environment.

While EVs hold promise as the future of personal transportation, their widespread adoption requires addressing seemingly minor yet potentially compounded issues. Among these factors, cost plays a crucial role, as adequate funding is essential to effectively address these environmental challenges.

## 2. Method and Materials

### 2.1 CO<sub>2</sub> and Microplastics from Transportation

#### 2.1.1 CO<sub>2</sub> from Vehicles

Road transportation is a major source of both CO<sub>2</sub> and microplastic pollution. According to the table that shows the breakdown of greenhouse gas emissions in 2016, road transportation accounted for 11.9% of the total emissions, which is equivalent to about 5.9 billion tons of CO<sub>2</sub>. Replacing 5.6% of conventional vehicles with electric vehicles in 2022 would reduce CO<sub>2</sub> emissions by 328 million tons. However, electric vehicles still bring in further environmental

impacts as they still produce microplastic emissions from tires, brake wear, and battery recycling. It is important to consider both the benefits and the drawbacks of electric vehicles for the environment.

Table 1 Global Greenhouse Gas Emissions by Sector (2016)

Sector	Subsectors
Agriculture, Forestry, and Land Use (18.4%)	Livestock and Manure (5.8%), Agricultural Soils (4.1%) Crop Burning (3.5%) , Deforestation (2.2%) Cropland (1.4%), Rice Cultivation (1.3%), Grassland (0.1%)
Waste (3.2%)	Landfills (1.9%), Wastewater (1.3%)
Industry (5.2%)	Cement (3%), Chemicals (2.2%)
Energy use in Industry (24.2%)	Iron and Steel (7.2%), Non-ferrous Metals (0.7%) Chemical and Petro-chemical (3.6%) Food and Tobacco (1%), Paper and Pulp (0.6%) Machinery (0.5%), Other Industry (10.6%)
Energy use in Transportation (16.2%)	Road (11.9%), Aviation (1.9%), Shipping (1.7%) Rail (0.4%), Pipeline (0.3%)
Energy use in Buildings (17.5%)	Residential (10.9%). Commercial (6.6%)
Miscellaneous Energy Use (15.3%)	Energy in Agriculture and Fishing (1.7%) Fugitive Emissions from Energy Production (5.8%) Unallocated Fuel Combustion (7.8%)

### 2.1.2 Microplastics

Microplastics are plastic pieces that measure less than five millimeters formed by the use of plastics. In 2022, 269,000 tons of microplastics went into the ocean where approximately 51 trillion microscopic pieces were found. As shown in the table below, one of the largest contributors to this problem comes from tires that generate microplastics from the road surface friction due to daily driving. About 28% of all microplastic emissions, equivalent to 75,320 tons, have resulted from tire wear.

Consider the massive Pacific Ocean garbage patch: a floating mass of plastic about twice as large as the state of Texas. Trillions of pieces of plastic form this body, along with many tons of microplastics where 28% of these pieces come from tires.



**Table 2 Source of Microplastics**

<b>Emissions Source</b>	<b>Percentage of Emissions</b>
Synthetic Textiles	35%
Tires	28%
City Dust	24%
Road Markings	7%
Marine Coatings	4%
Personal Care Products	2%
Plastic Pellets	0.3%

Plastic leakage was said to have been around 22 million tons, and this leakage is projected to double to 44 million in less than 30 years. This means that this plastic waste has the potential to double very soon and cause adverse effects on our environment. Ocean plastics have already caused significant damage to the aquatic environment, being a huge dangers to fish and turtles.

Plastics also last extremely long. While this may seem like a good quality for consumers, this is massively detrimental to the environment considering the fact that most plastics in nature will not fully decompose until hundreds of years into the future. With the upward trend of plastic production and leakage into the environment, this could potentially lead to some of the worst environmental and health crises humanity will see.

### **2.1.3 Comparison between CO<sub>2</sub> vs. Microplastics**

To compare the environmental impact of CO<sub>2</sub> and microplastics generated by vehicles, we have summarized the main sources and effects of these pollutants in Table 3. CO<sub>2</sub> is mainly emitted from the combustion of fossil fuels, while microplastics are shed from tires and brakes due to friction and weathering. Both pollutants can travel long distances via wind and water, and have negative consequences for the climate, ecosystems, and our health.

The table displays a comparison of emission amounts, decomposition spans, methods of reduction, environmental impacts, and severity of the problems within CO<sub>2</sub> and microplastics. There is much more CO<sub>2</sub> than microplastics, but CO<sub>2</sub> can more easily be reduced via human involvement than with microplastics. There is no practical way to reduce the amount of microplastics, we can only limit how much we produce. The environmental impacts of microplastics are also much harder to reverse as opposed to CO<sub>2</sub>'s effects, and microplastics will be present for a very long time as they have an extremely long decomposition span and are unable to be fully destroyed. Even with the high amounts of CO<sub>2</sub> right now, this number can go

down with today’s technology, but microplastics will only be set to increase until something is done to completely stop the rate or reduce the amount.

**Table 3 Comparison of CO2 and Microplastics**

	<b>CO2</b>	<b>Microplastics</b>
2022 Emission amount( tone)	327,868,800	75,320
Decomposition span	Varies (0–200 years)	>100 years
Method to reduction	Leveraging photosynthesis, direct air capture (DAC), or forest restoration	Impossible to get rid of effectively as microplastics can only be limited
Environmental impact	Global Warming, adverse weather conditions, unsuitable climates for certain environments	Aquatic life damage, toxic soil, and water leaching, poisoning of fresh water sources
Difficulty	Large amount	Long decomposition span

Plastic emissions pose a serious threat to our planet, along with carbon dioxide emissions. They contribute to global warming, climate change, and environmental damage. We need to address this problem urgently and effectively as soon as possible

## 2.2 Rolling Resistance and Microplastics Dynamics

### 2.2.1 Rolling Resistance

Tire rolling resistance is the energy that a vehicle needs to maintain a constant speed on a surface. It is influenced by several factors, such as tire construction, pavement texture, and stiffness, and environmental and traffic conditions. One of the consequences of tire rolling resistance is the generation of microplastics, which are small particles of rubber that are released into the environment. Microplastics from tire wear are a major source of plastic pollution in rivers and oceans and can affect ecosystems, wildlife, and human health. According to a recent study, tire wear in cities could pose up to a four-fold greater risk to the environment than other microplastics. It is generally expressed in the equation

$$F_r = c \cdot W$$

$$c = 0.005 + 1/p(0.01 + 0.0096\left(\frac{v}{100}\right)^2$$

where  $F_r$  is the frictional force,  $c$  is the rolling resistance coefficient, and  $W$  is the weight of the rolling object. The weight can be expressed as  $W=mg$ , where  $m$  is the mass and  $g$  is the acceleration due to gravity. The rolling resistance coefficient depends on the road surface condition and the tire pressure, which determine the deformation of the tire. ( $p$  = tire pressure (bars),  $v$ =velocity(km/h))

**Table 4 Rolling Resistance Coefficient over Different Surface**

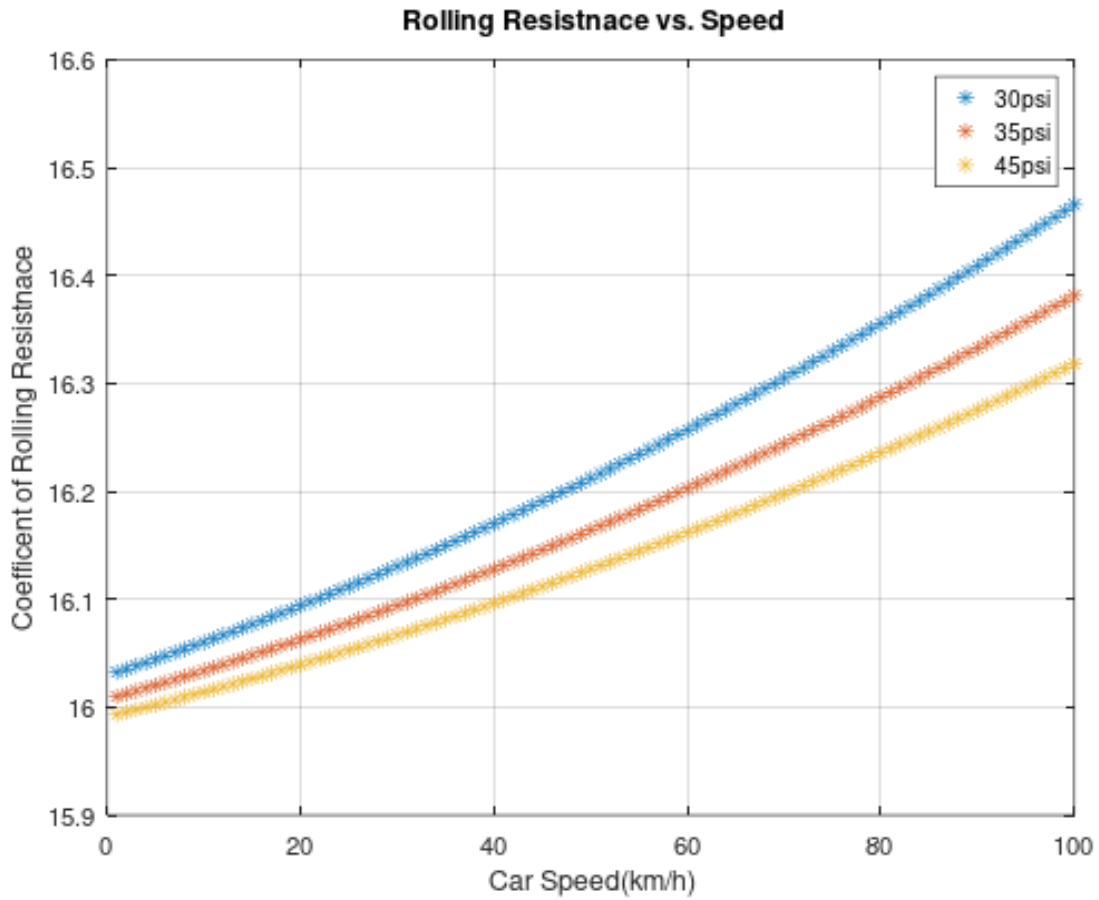
Rolling Resistance Coefficient	Situation/Surface
0.006 - 0.01	Truck tire on asphalt
0.01 - 0.015	Ordinary car tires on concrete, new asphalt, cobbles small new
0.02	Car tires on tar or asphalt
0.02	Car tires on rolled new gravel
0.03	Car tires on largely worn cobbles
0.04 - 0.08	Car tire on solid sand, loosely worn gravel, medium hard soil
0.2 - 0.4	Car tire on loose sand

### 2.2.2 Tire pressure and Rolling Resistance Coefficient

The graph below plots the coefficient of rolling resistance against the speed of a car in kilometers per hour. It can be observed that as car speed increases, the rolling resistance coefficient will also increase. Figure 1 also shows various tire pressures as an additional variable to consider. The higher the tire pressure, the lower the starting rolling resistance is. Higher tire pressure also reduces the increase in the rolling resistance coefficient. The pressure controls the contact patch area as shown in Figure 2. The area of contact patch worn from road friction. As shown in the equation above in 2.2.1, tire pressure and contact patch are inversely proportional. Since tire pressure is directly related to rolling resistance, contact patch and rolling resistance are inversely proportional. This means that as one increases, the other decreases.

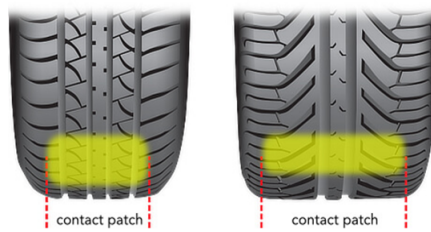
The low pressure gives a larger contact patch area, and it increases the microplastic emission from the area friction.

**Figure 1 Speed vs. Rolling Resistance Coefficient using Octave**



**Figure 2 Contact Patch Difference**

**Observational Data of Tire Wear**



**Table 5 Rolling Resistance power at 80 km/h for two different inflation pressures**

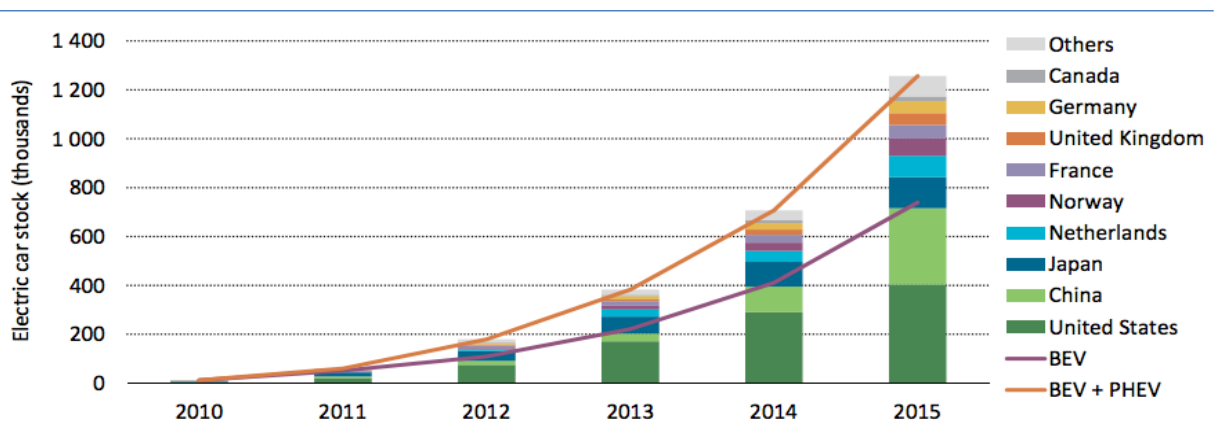
	Low-Pressure	High-Pressure	Difference (in %)
Pressure (bar)	1.8	3	66.7

RR Power at 80 km/h	770	650	-15.6
AEC (kWh/10km)	1.69	1.59	-4.6

### 2.3 EV facts weight

The most important factor of friction from rolling resistance is the load on each tire. The emission from microplastics is proportional to the weight of a vehicle whereas EVs have higher weights due to their batteries. Figure 3 displays the electric car stock in the world from the year 2010 to 2015. The graph shows a trend of a significant exponential increase in EV stock. China and the United States have adopted the greatest amount of electric vehicles, followed by the nation of Japan and various European countries. Given recent legislation and the growth of the EV market, it's likely that this exponential trend will only continue beyond our current time. It is important to investigate the impact of EV weight and its environmental impact in the early stage.

**Figure 3 Electric car stock per country**



Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

The table below displays the weights of various cars, both internal combustion and electric. Information was gathered about a multitude of different cars of different classes from different manufacturers. Most of the vehicles selected had both combustion and electric counterparts for a more fitting comparison. The difference between weights was then divided by the EV weight to find the percent increase between vehicle weights. Generally, electric vehicles tend to be much heavier due to their large battery packs and powertrains. As a result, the EVs can be anywhere from 10% to 49% heavier than their conventionally powered counterparts. The difference can go from just a few hundred pounds to a ton. On average, the weight difference was found to be 27%. Even if the car is not the same model, differently powered vehicles in the same class will generally be heavier if they are electric. For example, the Audi A6 can weigh up to 4,266 lbs, while the Porsche Taycan can weigh up to 5,119 lbs.

**Table 6 Vehicle Weight Table**

Model	ICE Vehicle Weight (lbs)	EV Weight (lbs)	Weight Percentage Increase
F150	4021	6015	49%
Kia Niro	3150	3854	22%
Volvo XC40	3861	4791	24%
BMW 4 Series & i4	3527	5018	42%
BMW 7 Series & i7	5095	5917	16%
Toyota Tundra & Rivian R1T	5095-5800	7148	23-40%
Genesis G80	4495	5047	12%
Genesis GV70	4584	5060	10%

This weight difference can largely be attributed to an electric vehicle’s powertrain. While a conventional gas-powered car derives its power from an internal combustion engine and fuel tank, an electric vehicle uses multiple electric motors powered by a large battery made up of rare earth metals, such as lithium and cobalt. While electric motors are very light, at around 150 lbs per motor, the battery packs that power those motors can weigh anywhere from 1,000 lbs to 2,000 lbs. Compared to an internal combustion engine, such as the Audi 2.0l turbocharged four-cylinder, which weighs only about 300 pounds, there is a significant difference in the weights of electric vehicles and conventional vehicles.

The table shows that electric vehicles are 27% heavier than their gas-powered counterparts, with many vehicles being more than 27% heavier. As a result of that weight difference, we may potentially see a massive increase in microplastic emissions if EVs are adopted. 2022 saw 269,000 tons of microplastics released, meaning that about 75,320 tons were emitted from tires if tires accounted for 28% of all microplastic emissions. If all cars on the road become electric, a 27% average weight increase would yield 20336 more tons of microplastic emissions. As stated previously, there is little to no way to recycle or dispose of microplastics. Waiting for them to decompose is an even greater issue, as man-made plastics can take hundreds of years to fully decompose. Due to the weight of electric vehicles, a great issue is presented.

**2.4 Other Factors for EV Batteries**

Tire emissions and microplastics aren’t the only environmental/economic issues surrounding electric cars. Electric vehicles may seem completely better than conventional vehicles, but this isn’t completely true. It’s true that electric vehicles tend to be less expensive to run on the day-to-day, but electric cars tend to be a lot more expensive to repair and maintain ((Henry, 2022)). Studies have found that repairing electric cars costs upwards of twice as much

as it would to repair a conventional automobile (S., 2022). Not only that, but battery replacement can be a hefty cost for owners. 8 to 12 years is the standard lifetime for a battery, and it costs around 15k to 25k to replace, while most engines can last much longer while only costing around 3k to 6k to replace ((*Costs of Electric Car Battery Replacement*, n.d.), (*How Much Does It Cost to Replace a Car Engine?* | Jerry, 2022)). Not to mention, most engine failures occur during a warranty period, meaning they can be replaced at no cost to the owner; it's likely that an EV battery replacement will need to happen years after the warranty expires. Worse still, an engine can be rebuilt if it's blown after a warranty. Most people won't be able to repair EV batteries on their own. Another place where electric vehicles fall short is range. Electric cars may have the edge in costs to run and fuel, but EV owners will often find themselves refueling more often, as conventional counterparts to electric vehicles tend to have better range (McAleer, 2022). For example, the Porsche Taycan has a range of about 200 miles (*Porsche Taycan - Porsche USA*, n.d.). A Porsche 911 has a range of 304 to 422 miles on a single tank of gas. That's nearly twice as much range from a relatively similar car. Electric vehicles also tend to be a lot heavier than conventional cars. On average, electric cars weigh about 25% more than their conventional counterparts (need to create a graph for the table we created). This not only affects electric vehicles in terms of safety and handling concerns, but it also adds strain on to road surfaces and tires ((*Access Denied*, n.d.))

**Figure 4 This shows various electric or PHEVS costs to replace a battery. Figures are given on how much money per kWh is needed for replacement.**



According to Figure 4, certain vehicles, such as the Chevrolet Volt and Hyundai Ioniq, have lower prices to repair batteries due to being plug-in hybrids. Fully electric vehicles will cost around \$15,000 to \$20,000 to replace batteries. The figure on price per kWh discloses the average cost to replace a battery per kilowatt hour.

### 3. Result

#### 3.1 EVs and Microplastics

Due to the generally higher mass of electric vehicles, the frictional force from rolling is proportionally increased. Since frictional force is applied onto the tires and the road is increased, the wear increases alongside it. As wear increases, the amount of microplastics increases from tires, and the amount of particles increases from the road, causing health problems among our population.

**Table 7 RR and Friction**

Model	ICE RR and Friction dry asphalt at 90 Kph	EV RR and Friction dry asphalt at 90 Kph	Percentage Increase in RR and Friction
Volvo XC40	205 N (0.205 kN)	256 N (0.256 kN)	20%
Ford F150	276 N (0.276 kN)	341 N (0.341 kN)	19%
BMW 4 Series (4 door) & i4	211 N (0.211 kN)	250 N (0.250 kN)	16%
BMW 7 Series & i7	240 N (0.240 kN)	264 N (0.264 kN)	9%
Mercedes GLB & EQB	208 N (0.208 kN)	247 N (0.247 kN)	16%
Toyota Tundra & Rivian R1T	298 (0.298 kN)	320 N (0.320 kN)	7%

Wheel slip occurs when the force applied to a tire exceeds the traction available to that tire (Nice, 2021). Force is applied to a tire in two ways: longitudinally when the torque is applied to the tire by the engine or the brakes to either accelerate or decelerate the car, and laterally, when the car drives around a curve and the ground applies a lateral force on the car to force it to change direction. During the acceleration of an electric vehicle, the sudden torque applied to the tires is far greater than what a combustion engine can apply, as the simplicity of electric motors compared to their internal combustion counterparts allows them to apply full torque on the wheels from the moment the engine is activated. Thus, the tires on electric vehicles tend to face far greater amounts of resistance during acceleration, causing them to wear quickly and deposit more microplastics.



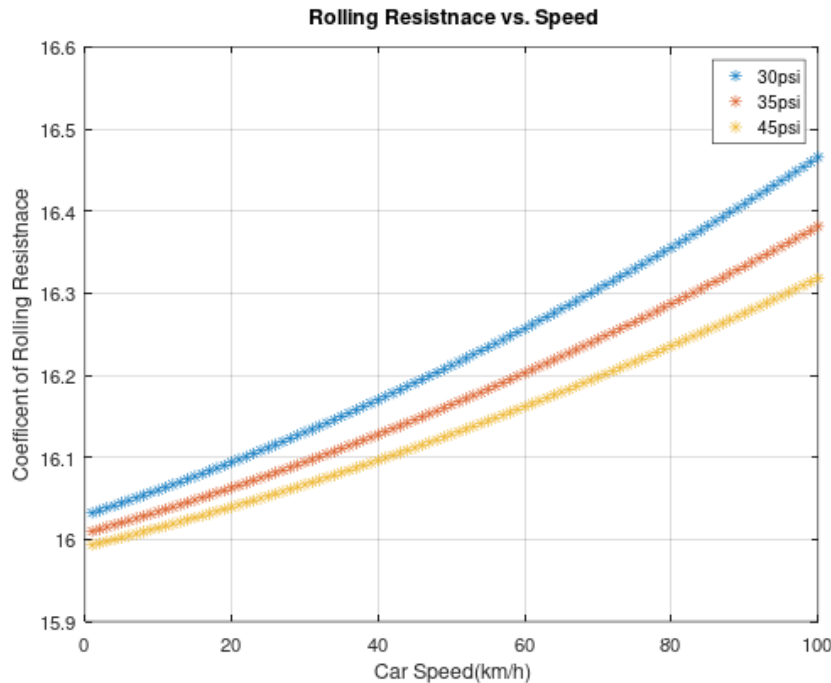
**Figure 5 Tire Wear**



From Figure 5, Images U1, U2, and U3 illustrate the wear of the tire to the point of replacement after 45,727 miles. Images N1, N2, and N3 show the new replacement tires and display references for when the tire was new. On average, tires are supposed to last for about 50,000 miles for internal combustion vehicles, which the images show after being replaced after 46k miles. Standard tires on electric vehicles typically last between 30,000 to 40,000 miles (Jones, n.d.). That is a 20%-40% range decrease compared to internal combustion vehicles like the Audi Q7 in the reference images. Furthermore, the Audi Q7 is not a light conventional vehicle weighing in at over 2 tons, meaning that electric vehicles wear out tires at a faster rate not only due to increased weight but also due to increased (instant) torque and regenerative braking. The weight is a big problem, but so is the instant torque. This is often one of the trademark characteristics of electric vehicles meaning car brands will advertise this to attract more buyers. All of these factors combined show that electric vehicles release more microplastics at a faster rate than typical vehicles, resulting in adverse effects on our health and the environment.

EVs (Electric Vehicles) cause the issue of road degradation to worsen as EVs are naturally heavier due to their high-capacity but heavy lithium-ion battery packs. An example of this is the recently launched Rivian R1T. It weighs over 3.5 tons making it nearly 2 times as heavy as a normal ICE (Internal Combustion Engine) vehicle, which usually weighs between 1.5 to 2 tons. The more weight there is on a road, the more friction it creates between the tire and the road, causing heat to build up and increased wear on the tire and road. Therefore, the amount of particles from both sources is increased and the cost of replacing the tire and repaving the road are going to be increased as they need to be more frequently done. Now, the way these particles are emitted from tires due to weight is through friction, rolling resistance, and torque.

**Figure 6 Rolling Resistance vs Speed Graph**



The graph above plots the coefficient of rolling resistance against the speed of a car in kilometers per hour. It can be observed that as car speed increases, the rolling resistance coefficient will also increase. The graph also shows various tire pressures as an additional variable to consider. The higher the tire pressure, the lower the starting rolling resistance is. A higher tire pressure also reduces the increase in the rolling resistance coefficient.

### 3.2 Tire Pressure Control and Vehicle Optimal Control

The RR coefficient is affected by the tire pressure in an inverse way. Table 8 below shows that EVs have a 21% higher pressure than conventional vehicles on average. However, EV tires have a shorter life span, being replaced every 20,000 to 25,000 miles compared to 50,000 to 60,000 miles for a conventional tire. This could be due to the uneven and heavier load distribution on each tire, and an EV's linear torque curve. A possible solution is to adjust the tire pressure according to the terrain conditions, and the vehicle dynamics can also be adjusted such as with changing speed, load, and maneuverability.

The passenger vehicle tire pressure is set to cover a range of terrains from dry conditions to wet or rough conditions. However, this means that the standard tire pressure is not optimal for dry asphalt and has a 10% margin for wet terrain handling. Moreover, the tire pressure changes during braking and acceleration, which can alter the vehicle's pitch and affect its performance and tire friction. A tire pressure control system is highly recommended for EVs to prevent further production of microplastics and worse handling (El-Zomor et al.).

**Table 8 Tire Pressure Comparison**

Model	ICE Tire Pressure	EV Tire Pressure	Tire Pressure Percentage Increase
Ford F150	35 psi (2.41317 bar)	42 psi (2.8958 bar)	17%
Mercedes GLB & EQB	30 psi (2.06843 bar)	39 psi (2.68896 bar)	24%
Volvo XC40	34 psi (2.34422 bar)	36 psi (2.48211 bar)	6%
BMW 4 Series (4 door) & i4	32 psi (2.20632 bar)	42 psi (2.8958 bar)	24%
BMW 7 Series & i7	34 psi (2.34422 bar)	43 psi (2.96475 bar)	21%
Toyota Tundra & Rivian R1T	31.5 psi (2.171849 bar)	48 psi (3.30948 bar)	35%

**Conclusion**

In theory, electric vehicles are a brilliant idea. EVs tick almost every bar for practicality, while also being an extremely ecologically friendly alternative for combustion-engined vehicles. Their benefits in convenience, comfort, and cost cannot be ignored, and neither can their effect on greenhouse gas emissions. So many of the harmful pollutants released into the atmosphere by combustion engines and gasoline can be reduced by the adoption of zero-emissions electric vehicles. Considering that 328 million tonnes of CO2 emissions can be essentially eliminated by the mass adoption of electric vehicles, there seems to be little doubt that EVs are the future of transportation.

However, the other downsides must be considered before the world can completely adopt electric transportation. Basic design flaws result in great negative impacts on electric vehicles, including production concerns, energy procurement and production, and most importantly, microplastic emissions. It was found that the weight of electric vehicles is directly related to microplastic emissions in a variety of ways. Not only does the average weight increase of electric vehicles have an effect on driving dynamics, but it also has an effect on tire wear. Heavier weight means more stress on the tires, leading to a greater rate of wear as the vehicle drives in comparison to the average combustion-engined vehicle. This greater rate of wear means more and more microplastics are released. Weight increase also means the frictional force of rolling resistance is increased, which also leads to a greater rate of tire wear. Both of these factors are of great concern, considering the massive potential adverse effects of microplastic emissions. Greenhouse gas emissions are an issue to consider, but microplastic emissions should not be ignored. Microplastics currently cannot be easily recycled or removed while also taking decades to fully decompose.

However, this does not mean electric vehicles should not be considered as a form of transportation. These solutions can be overcome through the employment of solid-state batteries and tire pressure control systems. Solid-state batteries would reduce the immense weight of EV batteries, which provide the bulk of the vehicle's additional weight over the combustion-engined vehicle. The pressure control system would adjust tire pressure according to conditions to allow tires to last longer, releasing fewer microplastics.

Electric vehicles are a new but revolutionary technology that is very much the future of transportation. There is no doubt that EVs will provide stability to the transportation sector in terms of emissions while offering a comfortable and convenient experience for the general public. However, before fully adopting electric vehicles in different sectors of transportation, there must be consideration as to the potential harmful effects their use may bring, and work to find solutions before a mistake is made.

## **Discussion**

Our research examined the process of how microplastics were generated by tires and their undisclosed effects on our health and environment; focusing on electric vehicles, there was a clear correlation with the increase of microplastic generation from electric vehicles via their tires due to their heavy weight, linear torque curve, and specially designed tires. This put electric vehicles in a spotlight that didn't seem so environmentally friendly in contrast to what is commonly marketed by vehicle manufacturers, where electric vehicles are shown as a flawless solution to our very well-known emissions problem. Our evaluations also showed the increase in tire pressure across the board for all-electric vehicles despite having wider contact patches than a conventional internal combustion vehicle, which resulted in electric vehicle tires having a lifespan of 20,000-25,000 miles compared to 50,000-60,000 for conventional tires. This meant that more microplastics were generated by electric vehicles, but they were also being generated at a significantly faster rate. This increased microplastic generation would have also correlated with an electric vehicle's weight coming from its large battery, instant torque from its motors and specific tires that purposely have a wider contact patch. There are limitations that present themselves as variables in road surfaces and conditions that would have certainly affected the generation of microplastics from tires, and not all car manufacturers were willing to disclose information on their electric vehicle models. While we believe that these limitations have not impacted the primary purpose of our research, more controls and future experiments conducted by us will be useful in helping our research as we would have better control and more accurate findings on the process of microplastic generation and the effects of doing so.

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### Works Cited

- Molden, N. (2022, May 18). "Gaining Traction, Losing Tread: Pollution from Tire Wear Now 1,850 Times Worse Than Exhaust Emissions." Emissions Analytics. [Link](#)
- Mathisen, G. (2021, July 3). "Microplastic Comes from Car Tyres, but People Would Rather Say No to Plastic Packaging." ScienceNorway. [Link](#)
- Wijesiri, B., Egodawatta, P., McGree, J., & Goonetilleke, A. (2015). "Influence of Pollutant Build-up on Variability in Wash-off from Urban Road Surfaces." *Science of the Total Environment*, 527–528, 344–350. DOI
- Kole, P. J., Löhr, A. J., Van Belleghem, F., & Ragas, A. (2017). "Wear and Tear of Tyres: A Stealthy Source of Microplastics in the Environment." *International Journal of Environmental Research and Public Health*, 14(10), 1265. DOI
- Long, M. (2022). "Surprising Plastic Pollution Statistics & Facts of 2022." Santa Cruz Works. [Link](#)
- "Costs of Electric Car Battery Replacement." (n.d.) [Link](#)
- McAleer, B. (2022, November 7). "Electric Car Battery Life: Everything You Need to Know." Car And Driver. [Link](#)
- "Porsche AG - Porsche USA." (n.d.) Porsche HOME - Porsche USA. [Link](#)
- "Porsche Taycan - Porsche USA." (n.d.) Porsche HOME - Porsche USA. [Link](#)
- Nice, K. (2021, June 12). "How Four-Wheel Drive Works." HowStuffWorks. [Link](#)
- Jones, P. (n.d.). "Do Electric Cars Go Through Tires Faster? (Yes – Here’s Why)." [Link](#)

# Understanding the Impact of Human Activities on California's Bees to Aid in their Protection By Jayden Kim, Taeho Lee, Justin Hong, and Emily Yi

## Abstract

This study investigates the impacts of increasing temperature and carbon dioxide emissions on bees in California. Our research methods included a Google search of existing literature and household surveys. We found that climate change exacerbates issues facing bees, including temperature and drought. Our survey results showed a relationship between the time it takes for water to heat up and the age of the water heater and ambient temperature. We suggest that future studies could focus on the effects of environmental change on domesticated bees and differences in physiological responses among different species of bees. We also discuss examples of successful policies to protect bees, such as bans on neonicotinoid-based pesticides, and suggest potential laws and solutions for California. Overall, our findings suggest that environmental regulations and policies related to carbon emissions and climate change are important for protecting bees in California, and that individual actions can also make a difference.

## Introduction

Climate change and the increase in temperature are causing numerous significant issues in California, affecting its ecosystems, animals, and humans. These issues include coastal erosion, sea-level rise, coastal flooding, loss of the Sierra Nevada snowpack, reduced water supply, deforestation, and an increased risk of wildfire (CA Office of the Attorney General, 2022).<sup>19</sup> Bees, in particular, are significantly affected by these problems. With 1600 species of native bees in California (UC Davis Arboretum, 2018)<sup>20</sup>, bees play a crucial global role by providing essential pollination services (Khalifa et al., 2021)<sup>21</sup>. However, bee populations are declining due to habitat loss, wildfires, and other stressors. If bee populations continue to decline, the consequences could be dire for California's economy and ecosystems (Sumner et al., 2014)<sup>22</sup>.

In this study, we use a literature search of existing studies and a household survey to investigate the impacts of climate change-related and non-climate change-related issues on California bees. We also examine existing policies and household water usage in California. Our research questions are as follows:

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19 California Department of Justice - Office of the Attorney General. (2023). Climate Change Impacts in California. State of California Department of Justice. Retrieved June 30, 2023, from <https://oag.ca.gov/environment/impact>

<sup>20</sup> Anonymous. (2018, April 3). Beyond the honey bee: Learn more about California native bees. UC Davis Arboretum and Public Garden. Retrieved January 2, 2023, from <https://arboretum.ucdavis.edu/blog/beyond-honey-bee-learn-more-about-california-native-bees>

<sup>21</sup> Khalifa, S. A. M., & Elshafiey, E. H. (2021, July 31). Overview of bee pollination and its economic value for crop production. *Insects*. Retrieved January 2, 2023, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8396518/>

<sup>22</sup> Sumner, D. A. (2014). The economic impacts of the California almond industry. *Economic Impacts of California Almond Industry*. Retrieved January 3, 2023, from [https://aic.ucdavis.edu/almonds/Economic%20Impacts%20of%20California%20Almond%20Industry\\_Full%20Report\\_FinalPDF\\_v2.pdf](https://aic.ucdavis.edu/almonds/Economic%20Impacts%20of%20California%20Almond%20Industry_Full%20Report_FinalPDF_v2.pdf)

- 1) What climate change-related issues, such as drought, affect California bees?
- 2) What non-climate change-related issues impact California bees?
- 3) How do existing policies contribute to or help the current challenges faced by bees in California?
- 4) What factors affect household water usage in California?



## Google search of existing literature

### *Issues facing bees exacerbated by climate change*

As of 2022, California has designated four species of bees (the western, Franklin's, Suckley cuckoo, and Crotch's bumble bee) for protection under the California Endangered Species Act (Ca.gov., 2022)<sup>23</sup>. Since 2018, the government has mandated that anyone relocating bees and hives must record and register the owner's information, as well as the number of bees, hives, and colonies within 30 days of arrival in California (Fitchette, 2018)<sup>24</sup>. Bees heavily rely on scent for communication and locating pollinators and their hives. Carbon emissions pose a significant challenge for bees in California due to the substantial quantities produced. Current preservation policies for bees have become major concern around California. California Assembly Bill 32 is one such legislation that requires the state to reduce its carbon emissions to 1990 levels by 2020, which is a 15 percent decrease from regular carbon production (AB 32, 2018)<sup>25</sup>. AB 32 has been successful in reducing greenhouse gas emissions in California, going from 14.0 metric tons per person in 2001 to 10.5 metric tons per person in 2019, decreasing by 25 percent and being half of the national per capita (California is below the 2020 target for GHG emissions in 2021). However, on a national scale, carbon dioxide production has actually

23 California Department of Fish and Wildlife. (2022, December 14). CDFW Seeks Public Comment Related to Crotch's Bumble Bee, Franklin's Bumble Bee, Suckley's Cuckoo Bumble Bee and Western Bumble Bee. Retrieved June 30, 2023, from

[#8203">https://wildlife.ca.gov/News/cdfw-seeks-public-comment-related-to-crotch-s-bumble-bee-franklin-s-bumble-bee-suckleys-cuckoo-bumble-bee-and-western-bumble-bee&#8203;](https://wildlife.ca.gov/News/cdfw-seeks-public-comment-related-to-crotch-s-bumble-bee-franklin-s-bumble-bee-suckleys-cuckoo-bumble-bee-and-western-bumble-bee)

24 Fitchette, T. (2018, October 26). New California law aims to protect pollinators. Farm Progress. Retrieved January 6, 2023, from

<https://www.farmprogress.com/insects/new-california-law-aims-protect-pollinators>

25 California Air Resources Board. (2018, September 28). AB 32 Global Warming Solutions Act of 2006. CARB. Retrieved January 6, 2023, from

<https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006>



increased. NOAA's Mauna Loa Atmospheric Observatory recorded 421 parts per million of carbon dioxide in May 2022, a 1.8-parts-per-million increase in carbon dioxide production over the prior year. California may be decreasing in GHG emissions, but nationally, this number has been going up (NOAA, 2022)<sup>26</sup>.

We are currently in an era of technological advancement where our lives rely heavily on technology. Certain technologies, such as cars and factories, are powered by fossil fuels. Widespread use of fossil fuels has led to global warming and subsequently, an increase in temperature. The number of bees has decreased dramatically as carbon dioxide levels and temperatures rise. According to the United States Department of Agriculture (USDA, 2022)<sup>27</sup>, some of the reasons why the bees are dying are because of how the increase in carbon dioxide is causing changes in the weather, altering the relationships between plants and their pollinators. All of this is causing nutritional stress, which is a large factor in causing bee extinction (Conservation International, 2022)<sup>28</sup>. Another consequence of rising temperatures is habitat loss. Fossil fuel usage, coupled with changes in land use, resulted in 38 billion tons of CO<sub>2</sub> emissions in 2020, with around 5 billion tons were due to land use change and the rest were from fossil fuels (GCP, 2021)<sup>29</sup>. Through the large release of CO<sub>2</sub> emissions, it causes the acidity of the oceans to rise, harming the respiratory system and several other public health conditions affecting humans. Habitat loss evicts bees, and the bees fail to migrate to cooler areas because of the increase in temperature (Conservation International, 2022)<sup>10</sup>. Conservation International (2022) explains, "A study on bumblebee migrations found that bee territories have shrunk by nearly 231 km (200 miles) in North America and Europe." The failure to migrate causes a large population of bees to die from heat, and it continues to show how much of an effect carbon dioxide has on bees (Conservation International, 2022)<sup>10</sup>.

Climate change has disrupted the relationships between plants and pollinators. Conservation International (2022) describes how rising temperatures affect the timing of flower blooms. With higher average monthly temperatures, flowers may bloom earlier in the spring, potentially leading to a seasonal timing discrepancy between when flowers release pollen and when bees are prepared to feast on that pollen. Even a small misalignment of three to six days can significantly impact bee health, reducing their reproductive capacity and weakening their resistance to parasites and predators.

The increase in carbon continuously affects global warming. The sudden increase in global warming is affecting UV rays and polarized light. Polarized lights consist of light waves that vibrate in only one direction and can be observed through the reflections of undisturbed

26 NOAA. (2022, June 3). Carbon dioxide now more than 50% higher than pre-industrial levels. National Oceanic and Atmospheric Administration. Retrieved January 6, 2023, from

<https://www.noaa.gov/news-release/carbon-dioxide-now-more-than-50-higher-than-pre-industrial-levels> Are honey bees native to North America? (n.d.). | U.S. Geological Survey

27 Cox-Foster, D., & DeGrandi-Hoffman, G. (n.d.). Bolstering Bees in a Changing Climate. Agricultural Research Service, U.S. Department of Agriculture. Retrieved June 30, 2023, from

<https://tellus.ars.usda.gov/stories/articles/bolstering-bees-in-a-changing-climate/>

28 Duran, L. (2017, August 19). The buzz on climate change: It's bad for bees. Conservation International. Updated August 22, 2022. Retrieved June 30, 2023, from

[https://www.conservation.org/blog/the-buzz-on-climate-change-its-bad-for-bees&#8203;`oaicite":{"number":1,"metadata":{"title":"","\n\n\t](https://www.conservation.org/blog/the-buzz-on-climate-change-its-bad-for-bees&#8203;`oaicite)

29 Global Carbon Project. (2021, November 4). Global Carbon Budget 2021. Global Carbon Project. Retrieved July 9, 2023, from

[https://www.globalcarbonproject.org/carbonbudget/archive/2021/GCP\\_CarbonBudget\\_2021.pdf](https://www.globalcarbonproject.org/carbonbudget/archive/2021/GCP_CarbonBudget_2021.pdf)



water, glass, and sheet plastic. These lights have unique patterns that bees use to navigate. On the other hand, with the increase in global warming, the patterns of polarized lights change, causing many bees to become lost and eventually die (NCBI, 2011).<sup>30</sup>

Not only that, but several other factors associated with climate change have an important impact on bees. The change in temperature associated with global warming can cause an increase in humidity because warm air can hold more water vapor. That water vapor will eventually make the air more humid through evaporation. Changes in humidity and temperature affect bees in different ways. Not only does humidity indirectly affects the bees by making the temperature feel hotter and more humid, but it also directly affects them. If the optimal humidity rises above 60%, it poses a large risk to the beehives, because it can cause a risk to honey and comb production, impact pests, and cause infestations inside the hive (BeeKeepClub, 2022)<sup>31</sup>. The reduced potential in honey production is very important because it is the bees' main form of food; a decrease in it is therefore very concerning, despite the fact that bees consume plants (Palmer, 2016)<sup>32</sup>. In one study, pollen samples were collected over time from 1842 to 2014 (Ziska et al., 2016)<sup>33</sup>. This rise in pollen can most likely be credited to the fact that elevated CO<sub>2</sub> encourages the starchier parts of plants to grow more rapidly. In terms of the goldenrod plant, the increase in growth leads to a decrease in the total amount of protein. As a result, the goldenrod consumes star pollen, which has a significant impact on pollen and bees because pollen is considered “bees dofood” for bees (Palmer, 2016; Ziska et al., 2016)<sup>8,9</sup>. Continuous consumption of pollen can decrease a bee's life span since there is very little nutritional value in it when compared to other sources of food.

Drought has been a recurring and serious issue over the course of history. California's droughts in particular have always been an issue, and they are growing to become an even bigger issue as a result of climate change. A study states that “The four anthro-to-ogenic warming trends account for 5–18% of the JJ PDSI anomaly in 2014” (Williams, 2015)<sup>34</sup>. This data is explaining that the drought is worsening because of the climate, as the PDSI is a drought index, and this source is proving that the warming trends caused by man are affecting the drought. The lack of precipitation is too serious to ignore, as we are in the midst of the worst drought in 1200 years, with climate change as the primary cause.

The impact of droughts is much more devastating for animals, and especially so for creatures such as the bees, due to the fact that they need flowers to create food, and flowers need

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30 Kraft, P., Evangelista, C., Dacke, M., Labhart, T., & Srinivasan, M.V. (2011). Honeybee navigation: following routes using polarized-light cues. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 366(1565), 703-8. Retrieved June 30, 2023, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3049011/>

31 Bee Keep Club. (2022, May 16). How Honeybees Maintain Temperature and Humidity in a Beehive. Bee Keep Club. Retrieved January 6, 2023, from <https://beekeepclub.com/how-honeybees-maintain-temperature-and-humidity-in-a-beehive/#:~:text=The%20optimum%20humidity%20of%20the.and%20parasite%20infestation%20among%20others.>

32 Palmer, L., Robbins, J., & Graham, T. (2016, May 10). How rising CO<sub>2</sub> levels may contribute to die-off of bees. Yale E360. Retrieved January 2, 2023, from [https://e360.yale.edu/features/bee\\_collapse\\_co2\\_climate\\_change\\_agriculture](https://e360.yale.edu/features/bee_collapse_co2_climate_change_agriculture)

33 Ziska, L. H., Pettis, J. S., Edwards, J., Hancock, J. E., Tomecek, M. B., Clark, A., Dukes, J. S., Loladze, I., & Polley, W. H. (2016, April 13). Rising atmospheric CO<sub>2</sub> is reducing the protein concentration of a floral pollen source essential for North American bees. *Proceedings of the Royal Society B: Biological Sciences*. Retrieved January 2, 2023, from <https://royalsocietypublishing.org/doi/10.1098/rspb.2016.0414>

34 Williams, A. P., Seager, R., Abatzoglou, J. T., Cook, B. I., Smerdon, J. E., & Cook, E. R. (2015, June 11). Contribution of anthropogenic warming to California drought during 2012–2014. *AGU Publications*. Retrieved July 9, 2023, from <https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/2015GL064924>

water to grow. According to many studies, including one conducted by UC Davis, "drought conditions in the western United States in 2021 dried up bee forage" (UC Davis, 2022).<sup>35</sup> They even mention that over the last winter, many beekeepers lost even up to 70% of their bee population: "Some beekeepers who had been in business for decades shared that they lost 50% to 70% of their colonies over the winter of 2021–22." (UC Davis, 2022). Many say that bees are in a lot of danger due to the drought. In contrast, one study found that drought causes homeowners to remove their turf grass, which indirectly benefits the bees (Proctor, 2022).<sup>36</sup>

Bees play a crucial role in our daily lives, impacting our food supply and the economy. "The total economic value of pollination to crops worldwide is estimated at more than \$147 billion." (Entomologytoday, 2020). For people to neglect the issues, this problem has too high a value, whether one looks at it from an environmental or an economic perspective. Bee habitats were destroyed by droughts, and they are recovering well. "The findings indicate that drought has a substantial impact on the availability of floral resources in calcareous grassland, which will have consequences for pollinator behavior and populations." (Phillips, 2018).<sup>37</sup>

### Other Issues Facing Bees

The various species of parasites that attack honey bees are a constant stressor on the bee population. This is also the biggest factor in the constant uptick in the death of bees. Examples of such parasites are varroa mites (*Varroa destructor* and *V. jacobsoni*) and tracheal mites (*Acarapis woodi*). From disabling honey bees from the inside out to causing life-threatening deformations in the larvae of honey bees, these parasites pose a huge threat to the honey bee population, both now and in the future.

Tracheal mites infect queen bees, drones, and worker bees indiscriminately. These mites attach to the trachea, or breathing tube, of honey bees and reproduce inside of them. During this time, they also consume honey bee haemolymph. Unlike humans, bees don't have "blood," so their haemolymph is a similar equivalent. The infection caused by this can prevent normal respiration and resulting weakened and/or sick bees that have a substantially shortened life span. Tracheal mites also create infestations in hives when adult female mites are carried into the hive by a younger honey bee. Once inside, this mite is spread from bee to bee. The deadly combination of these mites, in combination with other factors such as diseases and weather, has the potential to lead to the failure and eventual death of a whole colony (BeeAware, 2022).<sup>38</sup>

Unlike tracheal mites, varroa mites affect the honey bees from the outside. Honey bees are also very ill-equipped to handle such parasites because varroa mites are not native to the United States and are originally from Asia. The predominant honey bees in California (*Apis*

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35 Durant, J. L. (2022, October 14). Climate Change Is Ratcheting Up the Pressure on Bees. UC Davis. Retrieved April 18, 2023, from <https://theconversation.com/climate-change-is-ratcheting-up-the-pressure-on-bees-192535>

36 Proctor, M. (2022). Effects of Drought on Habitat Quality for Native Bees in Residential Gardens of Claremont, CA. CMC Senior Theses. Retrieved July 10, 2023, from [https://scholarship.claremont.edu/cmc\\_theses/3066](https://scholarship.claremont.edu/cmc_theses/3066)

37 Phillips, B. B., Shaw, R. F., Holland, M. J., Fry, E. L., Bardgett, R. D., Bullock, J. M., & Osborne, J. L. (2018, July 24). Drought reduces floral resources for pollinators. NIH National Library of Medicine. Retrieved July 10, 2023, from <https://pubmed.ncbi.nlm.nih.gov/29652102/>

38 Bee Aware. (2023). Varroa Mites. Bee Aware. Retrieved January 13, 2023, from <https://beeaware.org.au/archive-pest/varroa-mites/#ad-image-0>

*mellifera*) did not evolve with proper defenses against these mites since they originate from different continents. After being introduced to the North American continent in the 1600s, the species were found in California in the mid-1800s (Wong, 2019)<sup>39</sup>. In comparison, varroa mites were first detected in California beehives in 1987 (UNR, 2022)<sup>40</sup>.

Varroa mites can be thought of as dirty needles and cause severe infections in honey bees (CMNS.umd., 2016).<sup>41</sup> In a serious infestation, they can cause bees to become crippled with the inability to fly. These mites survive by feeding on haemolymph while bees develop in their brood. This results in a significant decrease in the weight of the newly hatched bee. Drastic weight loss as a young hatchling creates an inability to fly and reduces a bee's hypopharyngeal glands. The result of this is less food for the other developing bees since these glands produce the royal jelly that is fed to potential queen bees. Additionally, worker bees that were infected by varroa mites when they were younger have a significantly reduced lifespan when compared to other bees.

Another stressor faced by bees is the constant exposure to pesticides, which builds up in their bodies and impacts not only their lives but also future generations. Pesticide exposure is a common occurrence for bees while pollinating in pesticide-treated agricultural areas. A common class of pesticides is called neonicotinoids (World Economic Forum, 2022)<sup>42</sup>. These insecticides are related to nicotine, and cause a host of problems for honey bees. One study has shown that female bees that were exposed to neonicotinoids as larvae had a 20% decrease in their offspring compared to unexposed female bees. Additionally, research indicates that bees affected by neonicotinoids in their first and second years of life also had a 72% decrease in their population growth rate (World Economic Forum, 2022)<sup>24</sup>.

Monoculture creates various issues for both honey bees and their environment since there is a direct correlation between the two. The technique of monoculture farming is often used because it is highly efficient at growing large quantities of a specific crop while also maximizing production costs. Farmers can then make a higher profit margin, thus creating a more profitable industry. One of the consequences of this is that monoculture farming creates a lack of genetic diversity among crops (Kogut, 2022)<sup>43</sup>. This lack of variation makes the plants more susceptible to pests and other threats. Because of this, farmers must use much higher amounts of pesticides in order to combat the constant threat. Unfortunately, this takes a toll on the honey bees that pollinate the crops.

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39 Wong, K. (2019, February 25). Foreign bees monopolize Southern California flower resources. Natural Reserve System. Retrieved January 8, 2023, from <https://ucnrs.org/foreign-bees-monopolize-southern-california-flower-resources/#:~:text=Native%20to%20Europe%2C%20the%20Middle,rush%20in%20the%20mid%2D1800s>

40 University of Nevada Reno. (2023). Varroa Mite Integrated Pest Management for Small-Scale Beekeepers in Nevada. Unr.edu. Retrieved January 13, 2023, from [https://extension.unr.edu/publication.aspx?PubID=2156#:~:text=The%20Varroa%20mite%2C%20Varroa%20destructor,\(Kraus%20and%20Page%201995\)](https://extension.unr.edu/publication.aspx?PubID=2156#:~:text=The%20Varroa%20mite%2C%20Varroa%20destructor,(Kraus%20and%20Page%201995))

41 University of Maryland. (2016). First Multi-year Study of Honey Bee Parasites and Disease Reveals Troubling Trends. Cmns.umd.edu. Retrieved July 10, from <https://cmns.umd.edu/news-events/news/first-multi-year-study-honey-bee-parasites-and-disease-reveals-troubling-trends>

42 Quinton, A. (2021, December 7). These pesticides can affect bee health for generations. World Economic Forum. Retrieved January 2, 2023, from <https://www.weforum.org/agenda/2021/12/neonic-pesticides-can-harm-bees-for-generations/>

43 Kogut, P. (2020, October 10). Monoculture farming explained: What are the pros and cons? EOS Data Analytics. Retrieved January 2, 2023, from <https://eos.com/blog/monoculture-farming/>

Additionally, monoculture also reduces opportunities for pollination by native bees, which may require the pollen from a certain genus or species of plant in order to survive (USGS, 2022)<sup>44</sup>. The lack of biodiversity within crops makes it harder for honey bees to find enough nutrients. This is the result of a monoculture farming system that often has miles and miles of fields growing only one plant. The lack of diversity in a bee's diet also causes many health deficiencies (Kogut, 2022)<sup>25</sup>.

Moreover, the technique of monoculture farming has severe environmental consequences. Unlike previous methods, the farming of only one specific crop creates root systems that aren't strong enough to withstand the soil structure around them and often leads to erosion or a loss in water consumption. Therefore, farmers who use monoculture farming must combat the lack of water retention in their farms by using even larger amounts of water. The water often comes from lakes, rivers, and reservoirs, which significantly increases the rate of depletion for this precious resource. This is especially alarming since it exacerbates droughts in places like California.

## Policy Context

Human activities, in addition to the natural environment, have an impact on bees. Since numerous laws and bills have the power to change how people farm, protect, and conserve bees, they have a significant impact on their ability to survive. The principal rules and restrictions enacted in California and across the country include those on pesticides, monoculture farming, water management, and wildfires.

**Pesticides:** Pesticides are regulated in the US, by the Environmental Protection Agency (EPA, 2016; 2022).<sup>45</sup> The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) grants the EPA the jurisdiction to control the sale, use, and distribution of pesticides. Furthermore, the Food Quality Protection Act of 1996 (FQPA) amended both FIFRA and FFDCA to establish higher safety standards for new pesticides used on food. The FQPA mandated that existing pesticides and preexisting tolerances be routinely reevaluated in accordance with the new, stricter guidelines. Although these are some significant laws, the Pesticide Registration Improvement Act (PRIA) also regulates the costs and deadlines for pesticide registration activities. Furthermore, the risk that pesticides pose to vulnerable or endangered species and their habitats is assessed through the Endangered Species Act (ESA), which employs the EPA to assess pesticide risk. Through this act, the harm that pesticides cause to endangered animals and their ecosystems is assessed and thoroughly ameliorated. When Trump permitted the use of bee-killing pesticides on more than 13.9 million acres, this demonstrated the EPA's authority. Sulfoxaflor was sprayed on approximately 14 million acres of crops that attracted bees, which led to the demise of countless endangered and rare bee species (NPIC, 2020)<sup>46</sup>.

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44 What is the role of native bees in the United States? (n.d.). | U.S. Geological Survey. Retrieved January 2, 2023, from <https://www.usgs.gov/faqs/what-role-native-bees-united-states>

45 Environmental Protection Agency. (2022, July 19). Policy Mitigating Acute Risk to Bees from Pesticide Products. EPA. Retrieved January 2, 2023, from <https://www.epa.gov/pollinator-protection/policy-mitigating-acute-risk-bees-pesticide-products>

Environmental Protection Agency. (2016, August). What Climate Change Means for California. EPA. Retrieved January 2, 2023, from <https://19january2017snapshot.epa.gov/>

46 Pesticide laws and regulations. National Pesticide Information Center. (2020, September 22). Retrieved January 2, 2023, from <http://npic.orst.edu/reg/laws.htm>

**Monoculture farming:** Monoculture farming involves cultivating only crops instead of a diverse range. Despite its risks, the profits are much higher for both farmers and the government, causing monoculture to continue to be utilized in the agriculture industry, leading to laws being created to further encourage farmers to practice monoculture farming, such as the Farm Bill.

The United States does have the Farm Bill to regulate some parts of the farming industry. The Farm Bill became permanent legislation in 1938. The bill promotes monoculture by incentivizing the planting of certain crops over others. It does this by providing income (security) for farmers cultivates certain staple crops, including corn, soybeans, wheat, and rice, plus dairy and sugar (Evan, 2017)<sup>47</sup>.

By incentivizing farmers who cultivate certain crops encourages monoculture farming, as farmers are now more encouraged to only plant certain commodity crops due to the money they get from the government. This can cause a huge issue due to monoculture farming being a huge issue for bees, especially due to them only being able to pollinate one type of crop instead of a diverse amount, which causes nutrients from the other crops to be unobtainable, decreasing their ability to go against diseases and bacteria (Prime Bees, 2017)<sup>48</sup>.

**Water management:** There are no laws regarding water usage by regular citizens, but companies do have a water management plan from the EPA that regulates their use of water. In California, a bill was signed called Senate Bill 606 and Assembly Bill 1668, which both regulate and set standards for per-person water usage (California Department of Water Resources, 2022)<sup>49</sup>. The law sets the standard at 55-gallon per person per day until 2025 and then 50 gallons in 2030 (California Department of Water Resources, 2022).<sup>31</sup> However, a significant challenge with these bills is the difficulty in accurately measuring the 55-gallon per day is only a requirement, not mandatory, and is not recorded by any governmental authority in any way. Both of these were made in 2018, and the effects on water management have actually been decreasing. Water usage has increased 18.9 percent more than 2 years ago, which is 1 year after the bill was made (Becker, 2022)<sup>50</sup>. Senate Bill 606 and Assembly Bill 1668 also do not enforce the law strongly enough. Although it is possible to monitor water usage closely, not fining or punishing those who go over the limit will not create a sense of necessity to change.

In the California Constitution, Article X Section 2 mandates that all water use be both reasonable and beneficial (Water Education Foundation, 2022).<sup>51</sup> However, this provision alone

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47 Evan, E. (2017, December 5). Monocultures in America: A system that needs more diversity. Debating Science. Retrieved January 2, 2023, from <https://blogs.umass.edu/natsci397a-eross/monocultures-in-america-a-system-that-needs-more-diversity/>

48 Primebees. (2017, June 8). Monoculture and the honey bee. Prime Bees - College Station Bee & Honey Farm. Retrieved January 2, 2023, from <https://primebees.com/2017/06/08/monoculture-and-the-honey-bee/#~:text=Monoculture%20leads%20to%20poor%20immune%20systems%20in%20bees&text=When%20bees%20only%20feed%20on,kill%20a%20lot%20of%20bees>

49 California Department of Water Resources (2022). Fast Facts on the Water Conservation Legislation. California Department of Water Resources. Retrieved November 26, 2022, from <https://water.ca.gov/>

50 Becker, R. (2022, May 10). How bad is water use in California? March is the worst so far, up 19%. CalMatters. Retrieved January 2, 2023, from <https://calmatters.org/environment/2022/05/california-water-use-up-19/#~:text=Californians%20used%2018.9%25%20more%20water,commercial%2C%20industrial%20and%20institutional%20users>

51 Water Education Foundation (2020). Water rights in California. Water Education Foundation. Retrieved January 2, 2023, from <https://www.watereducation.org/aquapedia/water-rights-california>

cannot determine whether or not water is used both reasonably and beneficially every single time a person or business uses it. The issue with these laws is the absence of penalties for non-compliance, and their enforcement is not stringent enough. Water management and policy are a huge part of the bee's survival, as extensive use of water can cause an already drought-prone California to further exacerbate the effects of droughts. Droughts are detrimental to bees, as temperature is a very sensitive aspect of the bee's survival and can quickly become fatal to the bees if temperatures increase due to droughts.

In addition, the 55 gallon limit could be lowered to conserve more water without having a detrimental effect on the average citizen of California. The executive director of the California Coastkeeper Alliance argues that the "water legislation is somewhat of a missed opportunity to make some deeper water conservation and efficiency gains." (Weise, 2018)<sup>52</sup> The issue is that most businesses and individuals are already meeting the limit set on water usage. In fact, "during California's recent five-year drought, a number of cities reduced total residential water consumption [to] well below 55 gallons per person per day." (Weise, 2018)<sup>54</sup> The water limits are not effective, since they do not actively seek to reduce water consumption for the average Californian, but instead to serve as an unenforceable hard limit on the relatively small percentage of people who are exceeding the 55 gallon a day limit. Since the California Department Of Water Resources states that "current statewide median indoor residential water use is 48 gallons per capita per day," with "a quarter of [California's] households already [using] less than 42 gallons per capita per day," this limitation is contributing minimally to outcomes that would likely happen regardless of its implementation. (California Department Of Water Resources, 2021).<sup>53</sup> More water could be conserved if the limit was more restrictive, and would serve to aid the average citizens of the state in conserving more water than they would normally do. Since the importance of water conservation cannot be overstated, both in the statewide effects of water shortage and more specifically in the conservation of bee populations, the water usage limit must be lowered.

California has water policy issues that remain unresolved. Richard Frank, Professor of Environmental Practice at UC Davis, even puts it this way, saying, "In California, we're dealing with 21st-century water supply issues using 20th-century water infrastructure and 19th-century water law" (Frank quoted in Bardeen, 2022).<sup>54</sup> There are minimal laws regarding California water supply, and existing laws are too vague and up for interpretation, such as the laws preventing overwatering, without a good explanation of what factors determine overwatering and proper watering. Furthermore, one of the only laws regarding water with any authority and enforcement is Article X Section 2 of the California Constitution, which states that "all water

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52 Weise, M. (2018, June 20). California Limits Daily Personal Water Use to 55 Gallons – Kind Of. House.gov. Retrieved July 4, 2023, from <https://docs.house.gov/meetings/II/II13/20190924/109994/HHRG-116-II13-20190924-SD004.pdf>

53 California Department of Water Resources (2021). State Agencies Recommend Indoor Residential Water Use Standard to Legislature. California Department of Water Resources. Retrieved July 4, 2023, from <https://water.ca.gov/News/News-Releases/2021/Nov-21/State-Agencies-Recommend-Indoor-Residential-Water-Use-Standard#:~:text=The%20report%20notes%20that%20the,gallons%20per%20capita%20per%20day>

54 Bardeen, S. (2022, February 28). Reforming water rights in California. Public Policy Institute of California. Retrieved January 2, 2023, from <https://www.ppic.org/blog/reforming-water-rights-in-california/>



rights and all uses of water must be reasonable” and that “beneficial uses include irrigation, domestic, municipal, industrial, hydroelectric power, recreational use, and the protection and enhancement of fish and wildlife” (Water Education Foundation, 2022)<sup>55</sup>. However, the laws are interpreted case- by-case, and as reasonable use is difficult to categorize, there are a lot of cases where they approve of something that does not seem reasonable or beneficial. For example, in early 2022, in Great Park, Irvine, the state approved their request to build a waterpark. However, this was executed in the midst of one of the driest periods in California history (CA Dept. of Water Resources, 2022)<sup>56</sup>. Clearly, these laws are not enough to reduce water use and, thus, limit the damaging effects of the California drought. California water laws are issues that the state must strive to resolve.

**Wildfire issue and restoration:** California does have the "wildfire and forest resilience plan," which covers everything from restoration and research of the topic to what we as citizens should do to help prevent wildfires (California’s Wildfire and Forest Resilience Action Plan, 2021)<sup>57</sup>. The plan also sets goals for the future on how we, as a community, can prevent massive wildfires. The government has added \$70 million worth of fire suppression resources since 2019 and an additional \$90 million worth of fire equipment in 2020. Not only that, California has been adding more firefighters, increasing the workforce by almost 900 new firefighters in 2020 to help with these fires (California’s Wildfire and Forest Resilience Action Plan, 2021)<sup>39</sup>. Wildfires affect areas such as forests, which are habitats for these bees, and the fires can potentially lead to these bees being displaced and dying as they lose their habitat. Most of these damages could have been remediated with the help of better regulations and enforcement by the California government. Forest guidelines in California do not have any laws that prohibit people from potentially causing a fire. Moreover, the guidelines that are currently in place are not heavily enforced, which makes the guidelines pointless if no punishment follows. California desperately needs to focus on the techniques and plans for limiting wildfires to create a safer environment for the people living in California and to help preserve the habitat for thousands of animals, one of them being bees.

## Results of the surveys

The survey involved 60 survey participants, all students aged 15 to 21 living in Southern California. Most participants were located in and around Irvine, Aliso Viejo, Laguna Niguel, Anaheim, and San Diego.

After surveying participants regarding how long it took for the water to heat up in order for them to be able to take a shower, the data concluded by showing a direct relationship between

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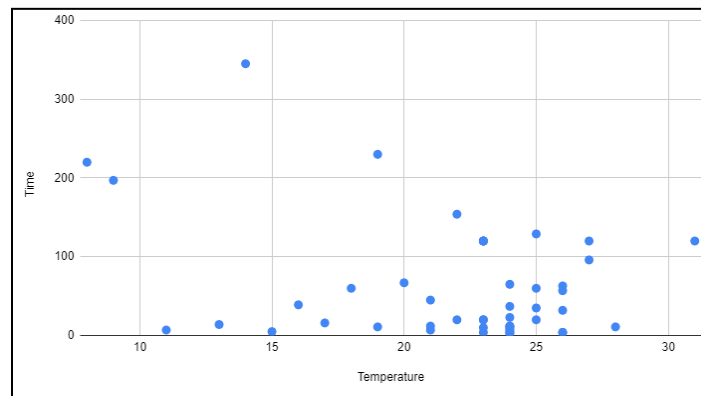
55 Water Education Foundation (2020). Water rights in California. Water Education Foundation. Retrieved January 2, 2023, from <https://www.watereducation.org/aquapedia/water-rights-california>

56 California Department of Water Resources (2022). Fast Facts on the Water Conservation Legislation. California Department of Water Resources. Retrieved November 26, 2022, from <https://water.ca.gov/>

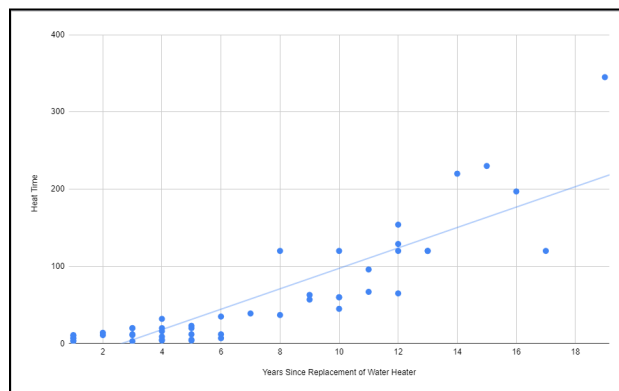
57 Newsom, G. (2021, January). California’s Wildfire and Forest Resilience Action Plan. Cal Fire. Retrieved January 3, 2023, from <https://www.fire.ca.gov/media/ps4p2vck/californiawildfireandforestresilienceactionplan.pdf>

the age of the water heating system and the time it took to heat up the water for usage (Figure 1). However, on the contrary, we found no relationship between the outside temperature and time to heat (Figure 2). This indicates that the age of the water heater is the most important factor in determining the time to heat and, thus, water usage.

There were a pair of responses from Big Bear, which is a very cold city; however, their responses were comparable to those of other participants with similar house ages. This once again leads to the conclusion that water heater age is a much more significant factor than the outside temperature. While the average age of the survey participants was quite young, the data collected included other members of their family, and data were collected on the average of each family member's time for heating up the water. In other words, each data point in Figures 1 and 2 represents the average time it takes each household to warm up the shower.



**Figure 1.** Graph showing the outside temperature on the x-axis and the time to heat the water for bathing (seconds) on the y-axis. This graph shows no linear relationship between the two variables.



**Figure 2.** A graph depicting the number of years since the water heater was replaced on the x-axis and the time required to heat the water for bathing (seconds) on the y-axis. This graph shows a linear relationship between the two variables, with the line of best fit described as  $y = 13x + 35$ .



## Discussion

Collecting additional information and data could be valuable for understanding the bee population. For example, information on the possibility of purposeful migration for bees will help determine whether it is an effective solution for protecting bees in light of climate change. Future studies could also focus on the effects of drought, temperature changes, and carbon dioxide on domesticated bees, enabling a comparison between existing studies of the effects of environmental change on wild bees and on domesticated bees. Habitat niches are also different among species of bees, and if research studies do not specify which species of bees were involved in their study, this severely limits the utility of the information for policy making. Thus, more information is needed about differences in physiological responses among different species of bees. Additionally, long-term data on bee populations and survivorship is needed to assess the impact of various laws on bee populations.

Although there is definitely room for improvement when it comes to actively protecting the bee population, there are many successful examples of policies to protect bees in other countries and states. For instance, Slovenia enacted a law banning the use of neonicotinoid-based pesticides in 2011, based on reports by beekeepers that the pesticides were causing bee deaths (Godin, 2020).<sup>58</sup> Soon after the ban, beekeepers reported seeing fewer bee deaths (Godin, 2020). In 2013, the European Union followed suit by banning neonicotinoid-based pesticides on crops pollinated by honey bees (Godin, 2020). In 2018, the EU ban on pesticides was expanded to prohibit its use on all crops (Godin, 2020). In the US, states decide whether they will ban the use of neonicotinoid-based pesticides, with Maine and New Jersey having banned it and other states placing restrictions on its use.

It is important to also consider potential laws and solutions that could be proposed for California that could benefit bees. For example, a law that limits monoculture and adds preservation areas for native plants to grow could be effective for protecting bees. Another useful law would be one that decreases carbon emissions and limits industrial activity in certain areas. The state of California should also consider imposing water usage restrictions to place higher value on ecological resilience.

## Methodology–Google Search of Existing Literature

Our research primarily focused on investigating the impacts of increasing temperature and carbon dioxide emissions on bees in California. Our initial literature search included searching for information on issues facing bees that are related to carbon emissions and climate change, including increasing temperature and drought in California. The following are example questions were searched in Google during our initial research:

- “How do carbon emissions affect bees?”
- “How does increased temperature affect bees?”

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58 Godin, M. (2020, May 6). What Slovenia could teach the world about saving bees. Time. Retrieved January 2, 2023, from <https://time.com/5815141/slovenia-bees-climate-change/>

- “How does carbon dioxide affect bees?”
- “How does drought affect bees?”
- “How is water usage and drought changing in California?”

Another focus of our research was on environmental regulations and policies that were related to issues of carbon emissions and climate change. We included the following Google searches in our research:

- “Policies that regulate carbon emissions”
- “Policies that regulate water usage”

As our research progressed, we expanded our literature search to include additional topics affecting bees in California, including issues facing bees that are not related to carbon emissions and climate change. We also explored additional regulations and policies that affect bees in other ways, including the following:

- “Policies that regulate pesticide use”
- “Policies that regulate fire management”
- “Policies that protect endangered and threatened animals”

### **Household surveys**

To collect data on water wastage at the household level while waiting for water to heat to the right temperature for bathing, we administered a survey using Google form. We recruited participants in the survey by sending the link to the Google form to our contacts, and by posting a link to the survey on our Instagram stories. The survey had 24 questions and took participants between 15-25 minutes to complete. Of the 90 total participants who filled out the survey, 60 answered the survey adequately enough for their data to be included in analyses.

Survey questions asked participants for the ambient temperature in their location at the time the survey took place. Participants were also asked to measure the time it took them to heat up the water coming out of the shower head, and to rate their water pressure on a three-point scale of high, medium, and low. Participants were instructed to use the following data collection method to measure the time-to-heat for their water: turn on their faucet at the same time as starting a stopwatch, and as soon as the water was deemed to be at the desired temperature, to turn off the stopwatch, and use the time given to complete the survey question. The survey also included a question about the age of participants’ water heater.

Prior to analysis, data were exported to Microsoft Excel and cleaned to ensure they were comparable. For data analysis, we compared the time to heat with the age of the water heater and with the ambient temperature. Data visualizations were created in Excel.

### **Conclusion**

Ultimately, small behavioral changes on an individual-level can benefit bees and serve as a solution to many of the problems mentioned above. For instance, ensuring that your house has a newer water heater will reduce overall water usage for your household. Finding plants that are

important for pollinators while also being drought-tolerant is also necessary. Finally, people should avoid using pesticides in home gardens and use natural pest control methods instead.

As a result of this study, it is clear that there is a huge problem with bees and we are not taking enough actions to prevent bee population loss and help bees adapt to climate change. This is something that needs more attention in the future if we want to protect pollinator populations. Ensuring that everyone takes individual actions to do their part in protecting bees as well as additional research alongside better and more effective policies will help save the bee population.

## Works Cited

- Anonymous. "Beyond the Honey Bee: Learn More about California Native Bees." UC Davis Arboretum and Public Garden, 3 April 2018, <https://arboretum.ucdavis.edu/blog/beyond-honey-bee-learn-more-about-california-native-bees>. Accessed 2 January 2023.
- "Are Honey Bees Native to North America?" U.S. Geological Survey, <https://www.usgs.gov/faqs/are-honey-bees-native-north-america>. Accessed 2 January 2023.
- Bardeen, S. "Reforming Water Rights in California." Public Policy Institute of California, 28 February 2022, <https://www.ppic.org/blog/reforming-water-rights-in-california/>. Accessed 2 January 2023.
- Becker, R. "How Bad Is Water Use in California? March Is the Worst So Far, up 19%." CalMatters, 10 May 2022, <https://calmatters.org/environment/2022/05/california-water-use-up-19/#:~:text=Californians%20used%2018.9%25%20more%20water,commercial%2C%20industrial%20and%20institutional%20users>. Accessed 2 January 2023.
- "Bee Aware." "Varroa Mites." Bee Aware, 2023, <https://beeaware.org.au/archive-pest/varroa-mites/#ad-image-0>. Accessed 13 January 2023.
- "Bee Keep Club." "How Honeybees Maintain Temperature and Humidity in a Beehive." Bee Keep Club, 16 May 2022, <https://beekeepclub.com/how-honeybees-maintain-temperature-and-humidity-in-a-beehive/#:~:text=The%20optimum%20humidity%20of%20the,and%20parasite%20infestations%20among%20others>. Accessed 6 January 2023.
- Burd, L. A. "Trump EPA OKs 'Emergency' Use of Bee-Killing Pesticide on 13.9 Million Acres." Center for Biological Diversity, 17 June 2017, <https://biologicaldiversity.org/w/news/press-releases/trump-epa-oks-emergency-use-of-bee-killing-pesticide-on-139-million-acres-2019-06-17/>. Accessed 2 January 2023.
- "California Greenhouse Gas Emission Inventory Program." CARB, 2023, <https://ww2.arb.ca.gov/our-work/programs/ghg-inventory-program#:~:text=Per%20capita%20GHG%20emissions%20in,average%20for%20per%20capita%20emissions>. Accessed 13 January 2023.
- "AB 32 Global Warming Solutions Act of 2006." California Air Resources Board, 28 September 2018, <https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006>. Accessed 6 January 2023.
- "CDFW Seeks Public Comment Related to Crotch's Bumble Bee, Franklin's Bumble Bee, Suckley's Cuckoo Bumble Bee and Western Bumble Bee." California Department of Fish and Wildlife, 14 December 2022, <https://wildlife.ca.gov/News/cdfw-seeks-public-comment-related-to-crotchs-bumble-bee>

- franklins-bumble-bee-suckleys-cuckoo-bumble-bee-and-western-bumble-bee. Accessed 30 June 2023.
- "California Laws Pertaining to Bee Management and Honey Production." California Department of Food and Agriculture, 2023, <https://www.cdfa.ca.gov/plant/pollinators/docs/Laws-Bee-Management.pdf>. Accessed 13 January 2023.
- "Climate Change Impacts in California." State of California Department of Justice - Office of the Attorney General, 2023, <https://oag.ca.gov/environment/impact>. Accessed 30 June 2023.
- "State Agencies Recommend Indoor Residential Water Use Standard to Legislature." California Department of Water Resources, 2021, <https://water.ca.gov/News/News-Releases/2021/Nov-21/State-Agencies-Recommend-Indoor-Residential-Water-Use-Standard#:~:text=The%20report%20notes%20that%20the,gallons%20per%20capita%20per%20day>. Accessed 4 July 2023.
- "Fast Facts on the Water Conservation Legislation." California Department of Water Resources, 2022, <https://water.ca.gov/>. Accessed 26 November 2022.
- "California Drought And Water Tracker." Cal Matters, 2023, <https://calmatters.org/california-drought-monitor/>. Accessed 6 January 2023.
- "Carbon Dioxide Emissions by State." Choose Energy, 10 October 2022, <https://www.chooseenergy.com/data-center/carbon-dioxide-by-state/>. Accessed 6 January 2023.
- Cook, C. N., Kaspar, R. E., Flaxman, S. M., Breed, M. D. "Rapidly Changing Environment Modulates the Thermoregulatory Fanning Response in Honeybee Groups." *Science Direct*, 18 April 2016, <https://www.sciencedirect.com/science/article/abs/pii/S0003347216000890>. Accessed 6 January 2023.
- Cox-Foster, D., & DeGrandi-Hoffman, G. "Bolstering Bees in a Changing Climate." *Agricultural Research Service*, U.S. Department of Agriculture, <https://tellus.ars.usda.gov/stories/articles/bolstering-bees-in-a-changing-climate/>. Accessed 30 June 2023.
- Corbet, S. A. "Temperature and the Pollinating Activity of Social Bees." *Resjournals.onlinelibrary.wiley.com*, February 1993, <https://resjournals.onlinelibrary.wiley.com/doi/10.1111/j.1365-2311.1993.tb01075.x>. Accessed 3 January 2023.
- Duran, L. "The Buzz on Climate Change: It's Bad for Bees." *Conservation International*, Updated 22 August 2022, 19 August 2017, <https://www.conservation.org/blog/the-buzz-on-climate-change-its-bad-for-bees>. Accessed 30 June 2023.
- Durant, J. L. "Climate Change Is Ratcheting Up the Pressure on Bees." *UC Davis*, 14 October 2022

# Investigating Relative Performance of Transfer and Meta Learning By Benji Alwis

## Abstract

Over the past decade, the field of machine learning has experienced remarkable advancements. While image recognition systems have achieved impressive levels of accuracy, they continue to rely on extensive training datasets. Additionally, a significant challenge has emerged in the form of poor out-of-distribution performance, which necessitates retraining neural networks when they encounter conditions that deviate from their training data. This limitation has notably contributed to the slow progress in self-driving car technology. These pressing issues have sparked considerable interest in methods that enable neural networks to learn effectively from limited data.

This paper presents the outcomes of an extensive investigation designed to compare two distinct approaches, transfer learning and meta learning, as potential solutions to this problem. The overarching objective was to establish a robust criterion for selecting the most suitable method in diverse machine learning scenarios. Building upon prior research, I expanded the comparative analysis by introducing a new meta learning method into the investigation. Subsequently, I assessed whether the findings remained consistent under varying conditions. Finally, I delved into the impact of altering the size of the training dataset on the relative performance of these methods. This comprehensive exploration has yielded insights into the conditions favoring each approach, thereby facilitating the development of a criterion for selecting the most appropriate method in any given situation.

## 1. Introduction

Traditionally, machine learning algorithms have heavily relied on extensive datasets. However, several factors can hinder the application of neural networks when dealing with limited data. For instance, certain domains, like medical diagnostics, face challenges due to the rarity of specific conditions or privacy concerns. Additionally, practical constraints, such as ethical and safety considerations, can limit data availability, as seen in the case of drug discovery, where assessing the efficacy of new drug candidates can be hindered by the potential toxicity, low activity, and low solubility of these molecules. Furthermore, data collection can be prohibitively expensive in certain scenarios, such as space applications. Lastly, the scarcity of computational or financial resources can hinder the retraining of algorithms with large datasets.

In contrast, humans exhibit the remarkable ability to learn from just a few examples. A child, for example, can recognize a giraffe after seeing only a handful of photos. This quick recognition stems partly from the child's prior exposure to various living beings, which has made them familiar with the key features of animals. Few-shot learning aims to emulate this capability by leveraging common representations to learn from a small amount of training data. In this paper, I explore different approaches to achieve representative learning, with a particular focus on transfer learning and meta-learning.

Few-shot learning, at its core, is the capacity to learn from a limited number of examples. To compensate for the absence of extensive datasets, as is typically the case in traditional neural network learning, few-shot learning methods seek to exploit alternative sources of information. This additional information can either be pre-existing knowledge, as demonstrated in transfer learning (Weiss), or extra knowledge derived from the small dataset itself, as exemplified by meta-learning (Finn).

While both meta-learning and transfer learning have garnered increasing interest in the machine learning community, there is a notable gap in the literature regarding a comprehensive comparative analysis of these two approaches. This void exists because these approaches have evolved independently, and until now, there has been insufficient evidence to conclusively compare their effectiveness. Despite the inherent flexibility that meta-learning offers, an existing comparative study (Dumoulin) has, thus far, suggested that transfer learning outperforms meta-learning. However, it is crucial to note that this field of research is dynamic and continually evolving.

In this paper, my primary objective is to bridge this gap by conducting an in-depth investigation into both meta-learning and transfer learning approaches. My aim is to establish a criterion for selecting the most suitable method in a given machine learning scenario. To accomplish this, I have expanded upon previous research by incorporating a recently acclaimed meta-learning method into our comparative analysis.

My investigation involved subjecting both meta-learning and transfer learning methods to various experimental conditions known to influence the performance of machine learning algorithms. These rigorous experiments allowed me to draw meaningful conclusions regarding the relative strengths and weaknesses of these approaches. As a result, I have identified a robust criterion for selecting the most appropriate algorithm in specific real-world scenarios.

The remainder of this paper is structured as follows: Following an introduction to the primary objectives of this investigation, I delve into the concept of few-shot learning. Specifically, I explore two distinct strategies for few-shot learning, namely transfer learning and meta learning. These sections serve as the foundation for the experiments detailed in the subsequent section. Lastly, I offer a concise summary of the key conclusions drawn from this research.

## **2. Main Objective**

The primary objective of this investigation was to establish a comprehensive criterion for selecting the optimal few-shot learning method tailored to specific scenarios. Traditionally, the fields of transfer learning and meta learning have evolved independently. In pursuit of this aim, I conducted an extensive review of the current state-of-the-art in both of these learning methodologies, primarily drawing from published research literature. Subsequently, I undertook experimental comparisons of these two methods within a framework initially proposed by Dumoulin and colleagues, expanding upon their work by incorporating a newly developed meta learning approach. This addition was driven by the overarching question: "Do the prior

conclusions regarding the relative performance of these two methods still hold true in light of recent advancements in meta learning?"

Furthermore, I addressed a critical question that remained unanswered in Dumoulin's work: How does the relative performance of these methods evolve when the size of the training dataset is altered? To explore this variation, I conducted an experiment, the findings of which have contributed to the formulation of a criterion for choosing the most suitable few-shot learning method in a given situation.

### **3. Two Alternatives for Few-shot Learning**

Few-shot learning is characterised by the ability to acquire knowledge and make predictions from a limited set of examples (Wang). In contrast to traditional neural network learning, which often relies on abundant datasets, few-shot learning methods seek to harness alternative sources of information. This supplementary information can take the form of pre-existing knowledge, as seen in the field of transfer learning, or additional insights derived from the small dataset itself, a hallmark of meta-learning.

The diverse landscape of few-shot learning algorithms can be broadly categorised according to the elements they leverage to achieve this goal. Within a typical machine learning system, three fundamental components exist: the model or hypothesis space, the data, and the algorithm. Various few-shot algorithms are strategically designed to exploit one of these components, often in conjunction with prior knowledge, to enhance their learning capabilities.

#### **3.1 Transfer Learning**

The human visual perception system undergoes continuous refinement through prolonged exposure to visual stimuli and interactions with the environment. As a result, it becomes proficient in recognizing objects using a relatively small set of distinctive features. Central to the concept of transfer learning is representation learning, which focuses on acquiring and mastering the essential representative features necessary for automated visual recognition.

Transfer learning methods typically employ a two-step procedure. Initially, a neural network model undergoes pre-training using a sizable dataset referred to as the "upstream dataset." Prominent examples of these upstream datasets include ImageNet and CIFAR. Subsequently, the model is fine-tuned using a task-specific dataset known as the "downstream dataset," which is comparatively smaller in size compared to the upstream dataset. The fascination with transfer learning methods gained traction alongside the rapid advancements in Convolutional Neural Networks (CNNs) after 2012 (Albawi). These CNNs were originally trained on extensive collections of images, notably the ImageNet dataset. The most successful architectures, such as VGG (Simonyan) and ResNet (He), featured deep structures with a multitude of parameters that required optimization with substantial datasets. Initially, these models excelled in applications where ample data was available. However, adapting them to different applications became problematic when relevant image collections were limited or



absent. Additionally, in cases where data was available, the computational resources required for retraining these models from scratch posed challenges.

Transfer learning methods emerged as a viable solution to these issues. Through transfer learning, a model initially trained on a typically large dataset can be fine-tuned using a smaller, task-specific dataset. For example, a neural network pre-trained on ImageNet can be fine-tuned to recognize various cat breeds, or a sentiment analyzer pre-trained on extensive movie review data can be fine-tuned for assessing sentiment in consumer goods reviews. In these applications, both pre-training and fine-tuning datasets were labelled, enabling both phases to follow the supervised learning paradigm. However, in the field of natural language processing (NLP), where labelled data is often scarce, transfer learning methods have been adapted to pre-train neural networks using unlabeled data (unsupervised learning) and fine-tune them with labelled data (supervised learning).

During the fine-tuning phase, not all pre-trained weights remain fixed; a subset of them is adjusted based on the new data. However, it is crucial to ensure that the number of parameters being adjusted does not lead to overfitting, especially when the size of the new dataset is significantly smaller than the number of available parameters. This risk can be mitigated by freezing part of the network. The choice of which layers to freeze is typically made based on heuristics (Kolesnikov). In convolutional neural networks, it has been observed that layers closer to the input handle generic image processing tasks, such as edge detection, while layers nearer to the output are more specialised for the target application (Xai).

Fine-tuning is often considered more of an art than a science (Stanford, Lecture 3), involving several critical decisions:

### **3.1.1 Determining how to unfreeze the network layers**

During the initial stages of the fine-tuning process, the entire neural network is held in a frozen state. This entails that all network layers are equipped with pre-trained weights. As the fine-tuning progresses, the number of layers that are allowed to adapt to the new task can be incrementally increased. This is achieved by gradually unfreezing layers that are located further away from the output layer. The feasibility of this approach depends on the size of the task-specific dataset; a larger dataset can support the fine-tuning of a greater number of parameters. In essence, if the downstream dataset is substantial enough, it becomes plausible to fine-tune the entire network.

However, when dealing with a smaller downstream dataset, unfreezing a large number of layers is not advisable. This is because it can lead to overfitting, as discussed in the previous section. In such situations, it becomes essential to consider the similarity between the source and target datasets. If the two datasets exhibit a high degree of similarity, it may be viable to directly apply pre-trained weights to all network layers during fine-tuning. Conversely, if the datasets are markedly dissimilar, it could prove advantageous to discard the pre-trained weights in some of the later layers and initialise them with random weights. This is because the original weights may lack relevance to the target task due to the substantial dissimilarity between the datasets.

### 3.1.2 Determining the learning rate

Within a neural network, the learning rate plays a pivotal role in controlling the pace of learning, specifically how rapidly the weights are adjusted during training. A common and effective practice is to initiate training with a smaller learning rate, especially when dealing with the initial layers of the network.

3.1.3 The Best Available Method for Transfer Learning: Big Transfer (BiT) Method  
The Big Transfer (BiT) method (Kolesnikov) has gained widespread recognition as one of the main approaches in the domain of transfer learning. It offers a relatively straightforward framework for transferring pre-trained general representations into specific problem domains or tasks. Much like other transfer learning methodologies, BiT leverages a vast dataset to acquire a comprehensive understanding of feature representations within the data. To illustrate, in the context of image processing, BiT has developed three distinct versions of its system, each trained on datasets of varying sizes. The largest among them has been pre-trained on an extensive dataset known as JFT-300M, consisting of a staggering 300 million noisily labelled images. This pre-training phase does demand substantial computational resources and time investment; however, it is a one-time expense, and the subsequent fine-tuning for downstream tasks incurs relatively lower costs. BiT distinguishes itself from prior methods in two key ways. Firstly, it simplifies the fine-tuning process by relying on straightforward heuristics to adjust hyperparameters for specific tasks. This approach streamlines the fine-tuning step, making it more accessible and efficient. Secondly, BiT deviates from the common practice of employing Batch Normalisation (BN) for data normalisation during training. Instead, it adopts Group Normalisation (GN), based on their observation that BN performs inadequately and imposes significant computational overhead when used for pre-training in distributed computing environments. GN proves to be a more effective choice in this context.

In image recognition tasks, BiT predominantly employs the Residual Network (ResNet), a well-established neural network architecture. Transfer learning remains an active area of research within the field of machine learning. Reported performance outcomes for transfer learning methods vary widely and are contingent on both the effectiveness of the algorithm and the datasets used in experimental settings.

### 3.1.4 Testing the Performance of Transfer Learning Methods

Until recently, the field of transfer learning lacked a universally accepted testing methodology, making it challenging to effectively compare different transfer learning methods. This difficulty stemmed from the fact that experiments often utilised distinct upstream (pre-training) and downstream (fine-tuning and testing) datasets. However, a significant development occurred with the release of the Visual Task Adaptation Benchmark (VTAB) paper in 2020 (Zhai). VTAB quickly gained widespread recognition for providing a robust framework that is both demanding and practical, facilitating the assessment of new transfer learning methods.

As previously discussed, transfer learning entails the process of fine-tuning a pre-trained model using new datasets, referred to as downstream datasets. Each of these datasets is designed with a specific objective in mind, known as a downstream task. The formulation and selection of these downstream tasks represent a critical aspect of an evaluation benchmark, as they must offer a sound basis for comparative analysis.

Given VTAB's focus on visual recognition task evaluation, the benchmark is constrained to tasks that rely solely on visual inputs. Within VTAB, the chosen 19 tasks are categorised into three main groups: natural, specialised, and structured. Natural tasks encompass images captured using standard cameras and span a range from generic to fine-grained and abstract images. Specialised tasks involve images of the world captured using specialised cameras, including medical and remote sensing images. Finally, structured tasks pertain to scenes' structural attributes and can be employed for tasks like 3D depth prediction or object counting. These structured tasks are often constructed using simulated environments.

Importantly, VTAB does not impose constraints on upstream training or transfer strategies, allowing researchers the flexibility to experiment and explore different approaches. In actual VTAB experiments, researchers have limited the size of the downstream dataset to 1000 instances, simulating conditions akin to few-shot learning. Consequently, for each downstream task, a random subset of 1000 images is selected for fine-tuning the neural network model. The assessment of performance in each task is conducted using another non-overlapping subset of 600 random images (referred to as the query dataset) from the same dataset collection. Performance is quantified as the average classification accuracy over the entire query set, providing a comprehensive evaluation of transfer learning methods.

### **3.2 Meta Learning**

Traditional deep learning faces a significant limitation: once a neural network is trained for a specific task, it cannot be readily repurposed for a closely related task without undergoing complete retraining from scratch. This issue is precisely what meta learning aims to address. It does so by cultivating a shared set of parameters among a group of interconnected tasks, enabling the model's reuse for new, related tasks. Meta learning offers a compelling advantage: it can accomplish tasks with minimal pre-existing data. An illustrative example is training an AI system to mimic the writing style of a particular individual or to adapt to a different language based on prior knowledge. Meta learning provides a viable alternative in scenarios where collecting extensive training examples is challenging due to data scarcity or resource constraints. Additional instances of its potential include per-language handwritten character recognition and personalised spam filtering. A common feature among these tasks is the presence of numerous tasks (e.g., languages for character recognition or individuals for personalised spam preferences), each with relatively limited examples. In standard deep learning approaches, success often hinges on the availability of abundant examples. However, in the context of meta learning, each language or individual in the mentioned examples is considered a distinct task. For instance, in handwritten character recognition, there are shared characteristics within each language, and for

spam recognition, there are common instances of spam applicable to almost everyone. Meta learning strives to separately discern these shared traits and task-specific attributes, facilitating adaptation to new tasks using a comparatively small dataset, with additional support from the shared characteristics.

Meta learning algorithms maintain two sets of parameters: one set is specific to individual tasks, while the other set is universal across all tasks. The latter is termed "meta parameters" and is determined through learning across a range of related tasks. In some research literature, the concept of learning to learn is described as the ability to choose a learning algorithm based on input data characteristics []. However, this notion is more aligned with automated machine learning rather than pure meta learning (Yaliang).

In a parallel manner to how neural network training seeks to enhance generalisation abilities (i.e., accuracy on unseen data), meta learning aims to elevate task generalisation (i.e., accuracy on unseen tasks). The concepts of meta-overfitting and meta-underfitting are analogous to overfitting and underfitting in traditional neural networks. For instance, meta-overfitting occurs when parameters are excessively optimised for the training tasks (Stanford, Lecture 4).

There are two prevailing viewpoints in the area of meta learning: the mechanistic view and the probabilistic view. In the mechanistic view, meta learning is essentially the training of a neural network using a meta-dataset, which encompasses multiple datasets, each associated with a different task. In contrast, the probabilistic view frames meta learning as the extraction of prior information from a set of tasks, enabling the efficient learning of new tasks. This prior knowledge is then leveraged to learn a new task with a limited number of training examples by inferring the most likely parameters.

### 3.2.1 Categorisation of Meta Learning Methods

Meta learning algorithms can be broadly categorised into four groups (Huisman).

- metric-based (or non-parametric) methods
- initialisation-based methods
- optimization-based methods
- model-based (or black box) methods

**Metric-based meta learning methods** are designed to acquire an appropriate metric space for the task at hand. For instance, when the goal is to discern the similarity between two images, a straightforward neural network is employed to extract features from both images. Subsequently, the similarity is quantified by measuring the distance between the features of these two images. The fundamental concept here revolves around task-specific learning, achieved by contrasting validation points with training points to predict the labels of corresponding training points. This approach finds extensive application in few-shot learning scenarios, where data

points are limited in number. Noteworthy examples of metric-based learning algorithms encompass siamese networks (Melekhov), prototypical networks (Snell), graph neural networks (Zhou), and relation networks (Hu).

**Initialization-based meta learning** methods are primarily focused on the acquisition of optimal initial parameter values. In a typical neural network training pipeline, random weights are initially assigned to the network. Subsequently, the process involves computing the loss by comparing the generated outputs with the expected outputs and subsequently minimising this loss through an optimization method, often gradient descent. The overarching goal is to calculate optimal weights with the objective of minimising errors. However, initialising the network with random weights can introduce challenges, making training more arduous and necessitating a substantial amount of data to achieve a satisfactory level of accuracy. This becomes particularly problematic when training data availability is limited. This challenge can be surmounted by initialising weights with values that are in close proximity to the optimal values, thereby expediting neural network convergence and learning. Initialization-based meta learning methods strive to compute these optimal weights through the learning of meta parameters. Notable algorithms in this category include MAML (Liu), Reptile (Nichol), and Meta-SGD (Li). During meta-learning, the full set of parameters is divided into two distinct groups. Meta parameters, also known as outer parameters, encompass those that are learned at the meta level. In contrast, task-specific parameters, often referred to as inner parameters, pertain to those fine-tuned for specific tasks. Achieving this segregation, however, has posed challenges as it necessitates identifying a subset of parameters suitable for meta-learning. Additionally, questions have arisen regarding whether a single initial condition suffices when confronted with a range of diverse tasks. Consequently, meta-learning algorithms have emerged that employ combinations of initial conditions to address this concern.

**Optimization-based methods** in the field of few-shot learning place a distinct emphasis on the acquisition of an optimised learning strategy. This emphasis arises from the inherent challenge of working with a limited amount of data in few-shot learning scenarios, which often proves insufficient for minimising errors through conventional optimization techniques like gradient descent. In these approaches, a two-network architecture is typically employed: a base network tasked with actual learning, and a meta network responsible for optimising the base network. Such methods find applicability in few-shot learning and in the enhancement and acceleration of many-shot learning.

**Model-based methods** represent a strategic departure from the conventional practice of iteratively computing optimal weights when dealing with limited datasets. Instead of this iterative approach, these methods employ a model to directly derive the optimal set of weights. This family of techniques is often referred to as black box models, owing to their relative lack of transparency and interpretable mechanisms.

### 3.2.2 Key Challenges in Meta Learning

Meta learning confronts two main challenges, the first of which is known as "negative transfer." This occurs when meta learning fails to provide a substantial advantage, making learning through independent networks a more favourable choice. Negative transfer typically arises due to two primary contributing factors. The first factor stems from optimization difficulties triggered by the varying learning rates across different tasks or parameter interference between tasks, a phenomenon referred to as parameter mixup. The second contributing factor relates to the limited representation capacity of the network. This limitation arises from the necessity for meta-learning networks to be larger in size compared to traditional neural networks, as they must learn both meta and task-specific parameters simultaneously.

### 3.2.3 Example Meta Learning Methods

The following meta learning methods were used in the experiments discussed in section 4 **Prototypical Networks** is a method that falls into the category of metric based meta learning methods.

**ProtoMAML** is a variant of the MAML that falls into the category of initialisation based meta learning methods.

**Data2Vec** (Baevski) is a method that falls into the category of metric based meta learning methods explained in section 3.3.1.

### Experimental Procedure

A standard neural network is tested for its ability to correctly classify a previously unseen example. In few-shot learning, the ability to correctly classify a previously unseen example using a neural network trained using only a small dataset is tested. The following key steps are followed in meta learning training and subsequent testing.

- Select a dataset
- Randomly choose a subsample of classes
- Randomly choose examples within the previously chosen subsample of classes and assign them either to the training set (support set) or the query set
- Conduct training and subsequent testing using the constructed support and query sets.

In meta learning, this approach to training is called episodic learning due to the way training episodes are constructed by random selection. Figure 1 shows an example meta learning training and test phase. In this example, each row in the meta-training block represents a training episode. In each episode, five classes have been randomly chosen and one example image per each class has also been chosen. The same approach has been used in constructing test episodes.

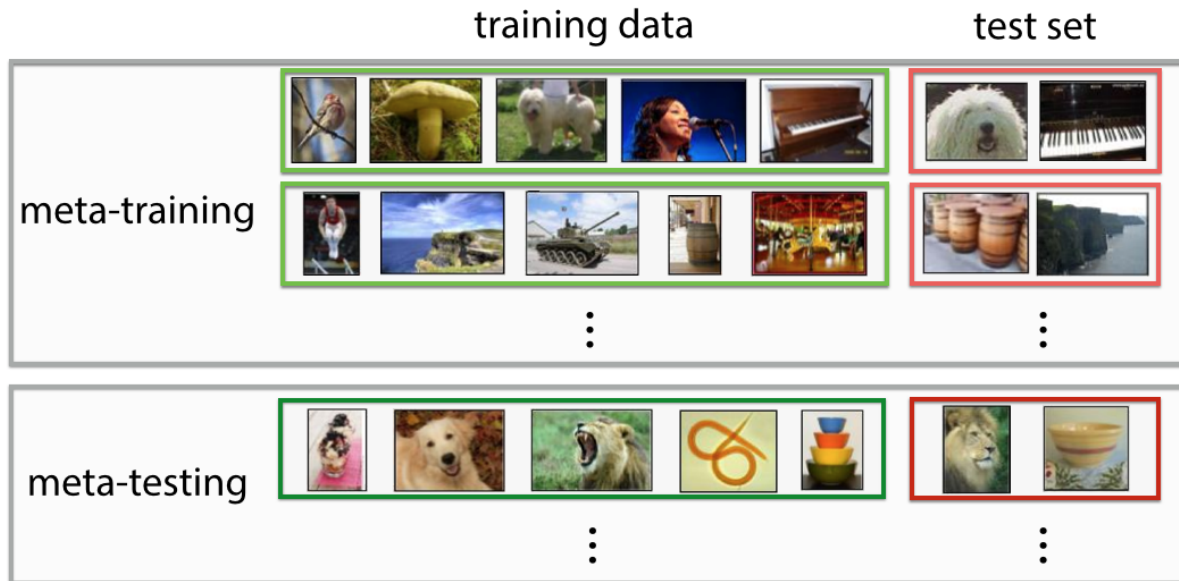


Figure 1 - An example meta learning process. (image credit - Stanford Meta Learning Lecture Series).

## Datasets

Until recently the two main datasets used for meta learning experiments were the Omniglot and mini-ImageNet. The Omniglot dataset contains 1623 handwritten characters taken from 50 different alphabets. Each data class contains 20 characters. Mini-ImageNet is a subset of the standard ImageNet dataset. It contains 100 ImageNet classes. Each class contains 600 examples. However, it has been recently argued that these datasets are not challenging or realistic enough to show improvements of the new methods and pave the way for further advancement. The other limitations highlighted include the homogeneity of the learning tasks (real life learning experiences are heterogeneous) and the measuring of generalisation ability only within the dataset.

The Meta-Dataset aims to overcome these limitations by introducing a realistic heterogeneity by varying the number of classes in each task and the size of the training set. It provides a more realistic environment to test few-shot learners. The size of the dataset is larger than the previously mentioned datasets and it is more diverse as well. This dataset has been constructed using 10 previous datasets. They are ILSVRC-2012, Omniglot, Aircraft, CUB-200-2011, Describable Textures, Quick Draw, Fungi , VGG Flower), Traffic Signs and MSCOCO. They contain images of different natural and human-made objects. There is a large variation of the granularity of images that increases the challenge of image recognition and generalization.

## 4. Experiments—4.1 Main Objective

The primary objective of this investigation was to establish a robust criterion for selecting the most suitable few-shot learning method in specific scenarios. In the initial phase of

experiments, the primary goal was to compare the performance of transfer learning and meta learning methods within the context of few-shot learning problems. This choice was motivated by a study conducted by Dumoulin in early 2021, which notably favored transfer learning methods over meta learning methods when applied to few-shot learning challenges. Additionally, a newly developed meta learning method known as Data2Vec was included to explore whether it had made strides in narrowing the performance gap. Subsequently, in the second experiment, the evaluation was extended to assess whether these findings persisted when utilising higher quality images.

Following the observations from these initial experiments, the investigation delved into the impact of reducing dataset size. There have been claims suggesting that meta learning could yield impressive results with relatively small datasets (Stanford). However, comparative experiments that assessed the relative performance of transfer and meta learning as dataset size was progressively decreased were lacking. This served as the objective of the third experiment, a crucial step in developing a comprehensive criterion for choosing the optimal few-shot learning method tailored to specific circumstances.

## **4.2 Experimental Framework–4.2.1 The Computing Setup**

Given that the core of the experiments revolved around the execution and evaluation of neural networks, it was important to establish the requisite hardware and software specifications. To implement the neural networks, the TensorFlow software library (<https://www.tensorflow.org/>) was employed. TensorFlow is a prominent open-source software library that enjoys extensive usage in the field of neural network development. The experiments were conducted on a personal computer (PC) running the Linux operating system, featuring an Intel Core i7 processor, 16 GB of physical memory, and a NVIDIA GPU card. The GPU card played an important role in accelerating neural network training through parallelization, significantly enhancing computational efficiency.

### **4.2.1 The Dataset**

Initially transfer learning and meta learning had been tested using different benchmarks. VTAB summarised in section 3.1.4 is one of the widely accepted benchmarks for transfer learning. Meta dataset, summarised in section 3.2.4, is one of the recent benchmarks for meta learning. In the previous study (Dumoulin), these two benchmarks were combined to provide a common framework. It was called VTAB+MD. I used the same setup since the objective was to compare against their results. In addition to the datasets, the Tensorflow hub makes pre-trained neural network models available. This helps save time and resources needed for training large neural networks from scratch. In this investigation, a pretrained neural network model was obtained from the Tensorflow Hub (<https://www.tensorflow.org/hub>). The particular model I used was called ResNet50 v2. It contained the parameters pre-trained using the large ImageNet dataset.



### 4.2.3 Experiments

The experimentation process was conducted in three distinct phases, each geared towards the overarching goal of pinpointing the most effective few-shot learning method tailored to specific situations.

In the first experiment, the primary aim was to address the question: "Can the novel meta-learning method, Data2Vec, bridge the performance gap between transfer learning and conventional meta learning methods?" This experiment closely followed the parameters employed by Dumoulin and colleagues in their prior experiments on transfer and meta learning methods.

With insights gained from the initial experiment, the focus shifted to the second phase. Here, the principal objective was to investigate the validity of the results when working with images of varying sizes, effectively representing different quality inputs. This inquiry was crucial because higher quality images have the potential to yield superior results, and the investigation sought to ascertain whether the same overarching trends persisted under these circumstances.

The third pivotal question sought to answer whether the supremacy of transfer learning over meta-learning remained intact when dealing with significantly reduced dataset sizes. This inquiry was motivated by the desire to explore whether the conclusions held when data availability was markedly limited.

The culmination of these inquiries was designed to provide a comprehensive answer to the ultimate question: "How can the most suitable few-shot learning method be selected in a given scenario?"

#### Experiment 1

In total there were 29 datasets. Training and testing procedures were run independently for each dataset.

For each dataset, 1000 images were randomly chosen and assigned to the training set. Another non-overlapping subset of 600 images were randomly chosen and assigned to the query set.

The transfer learning method used was the Big Transfer (BiT) method together with the ResNet50 v2 model. It was fine tuned using the chosen 1000 images and tested individually against each of the chosen 600 images. This procedure was repeated 100 times. Correct number of classifications was expressed as a percentage and averaged for 5 categories of datasets: VTAB (All); VTAB (Natural); VTAB (Specialised); VTAB (Structured); and Meta Dataset.

To assess performance of meta learning methods, Prototypical Networks, ProtoMAML and Data2Vec were used. They were trained using the same training dataset of 1000 images and tested using the same dataset of 600 images. However, following the standard procedure for meta learning, as explained in section 3.3.2, the following additional steps were executed. Randomly choose a subsample of classes and then randomly choose examples within the previously chosen subsample of classes and use them as training or test episodes as shown in figure 1. Again this procedure was repeated 100 times. Correct number of classifications was expressed as a

percentage and averaged for 5 categories of datasets: VTAB (All); VTAB (Natural); VTAB (Specialised); VTAB (Structured); and Meta Dataset. Appendix 1.2 shows part of the progress display during the training process.

Results were written into a file which was then automatically analysed for accuracy against the expected results. The overall performance was measured as the classification accuracy averaged over all test images. Results were aggregated for each data source.

## Results

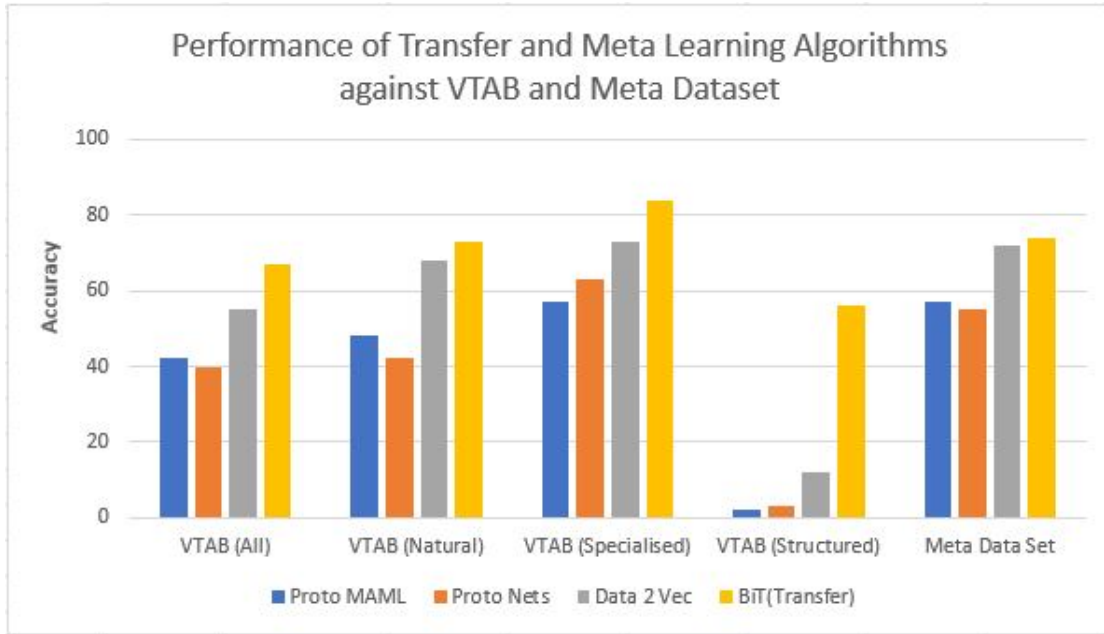


Figure 2 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset.

Figure 2 shows the results obtained using different transfer and meta learning methods for different data sources. As previously known, the transfer learning method BiT, that was explained in section 3.1.3, performs better than the meta learning methods when tested against the data sources (natural, specialised and structured) from the transfer learning benchmark VTAB. This is not surprising since these data sources are more suited for transfer learning. It has been previously reported that even against the Meta-dataset which was aimed for assessing meta learning algorithms, Prototypical Networks and ProtoMAML under-perform in comparison to transfer learning. My results re-confirm this observation. However, I have found that this performance gap is reduced by relatively better performance of the new meta learning method Data2Vec which has not been previously tested in this context. For the Meta Dataset, Data2Vec performs almost the same level as the transfer learning method. This is encouraging since these results show that the state of art of meta learning methods have improved.

Another observation is that the meta learning methods perform better with the Meta dataset. One reason for this behaviour may be that the tasks within this dataset show higher degree of

correlation than the tasks in the other datasets. This behaviour is consistent with the previous observations that meta learning methods work better with correlated datasets but under-perform in cross-dataset generalisation (Chen).

## Experiment 2

The main difference of this experiment was that input images with resolution of 224X224 were used. The resolution of the images used in the previous experiment was 126X126.

## Results

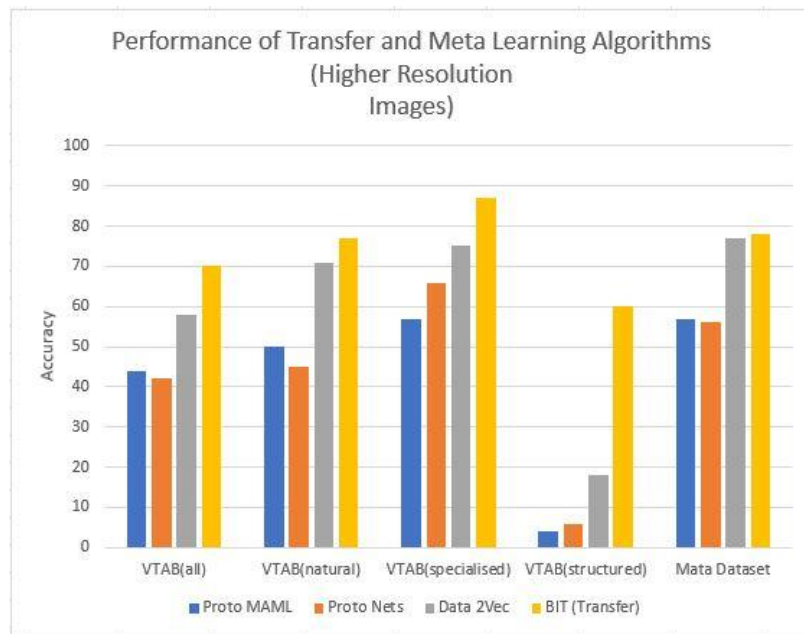


Figure 3 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset using higher resolution images.

Figure 3 shows the results obtained using higher resolution images. It shows that all methods perform better with higher resolution images. However, the overall distribution of performance stays the same. This provides further evidence that the new meta learning methods, Data2Vec has managed to bridge the gap between transfer learning and meta learning methods even though transfer learning still outperforms meta learning under the experimental conditions used in these two experiments.

## Experiment 3

The main difference of this experiment was that experiment 1 was performed using 1000 training images and 600 test images. In experiment 3, the same experimental procedure was repeated with 750, 500, 250 and 100 training images. Accordingly, the test was also reduced to 450, 300, 150 and 60 respectively. Results were separately recorded.

## Results

Figures 4 - 8 summarise the results obtained from the second experiment by incrementally reducing the size of the training dataset.

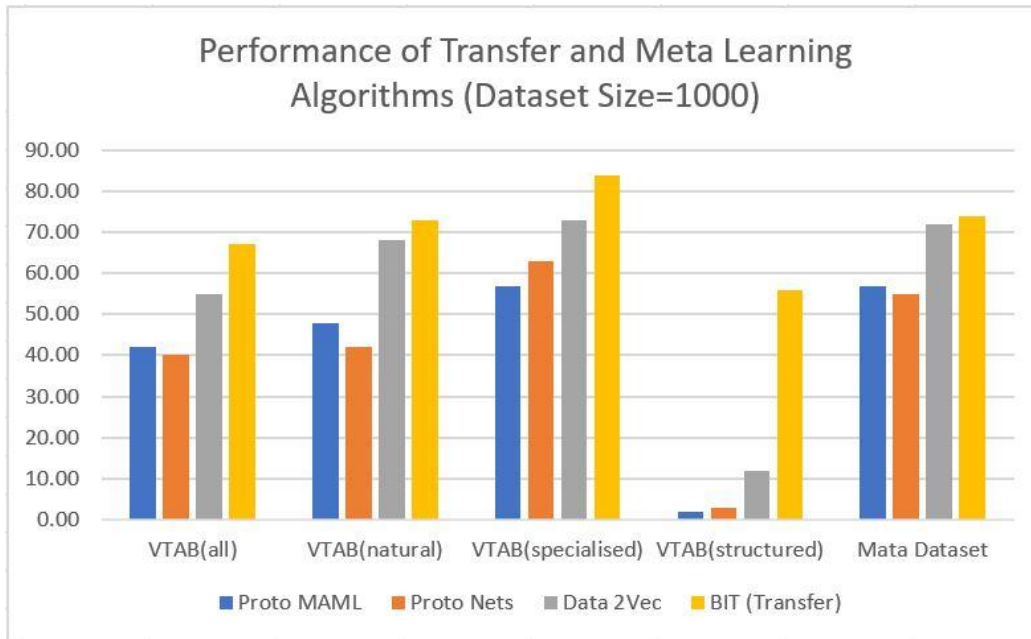


Figure 4 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset when the size of the training dataset is 1000 images.

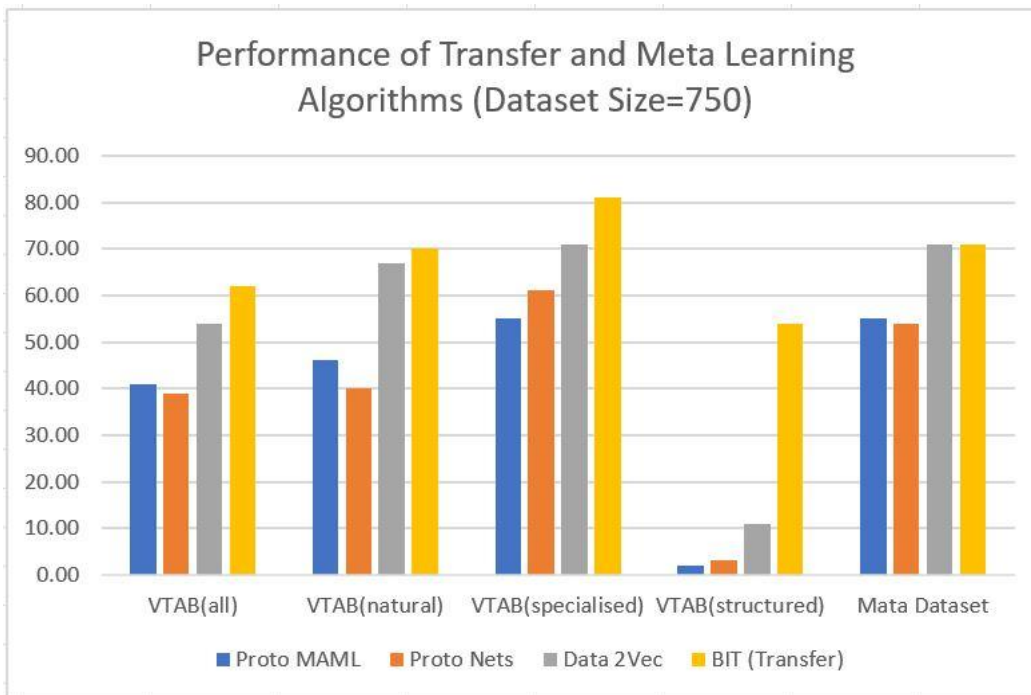


Figure 5 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset when the size of the training dataset is 750 images.

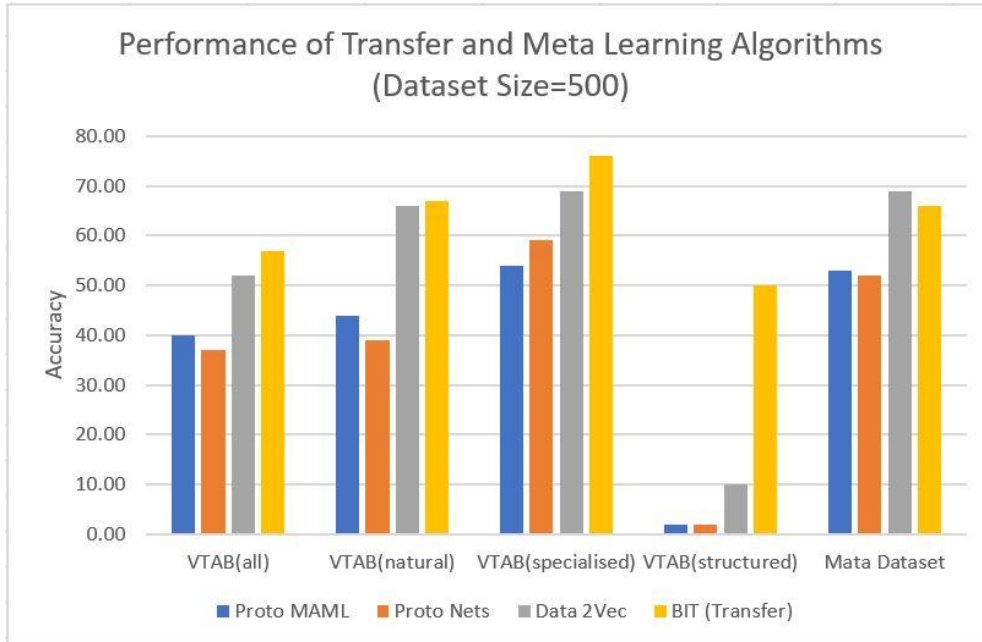


Figure 6 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset when the size of the training dataset is 500 images.

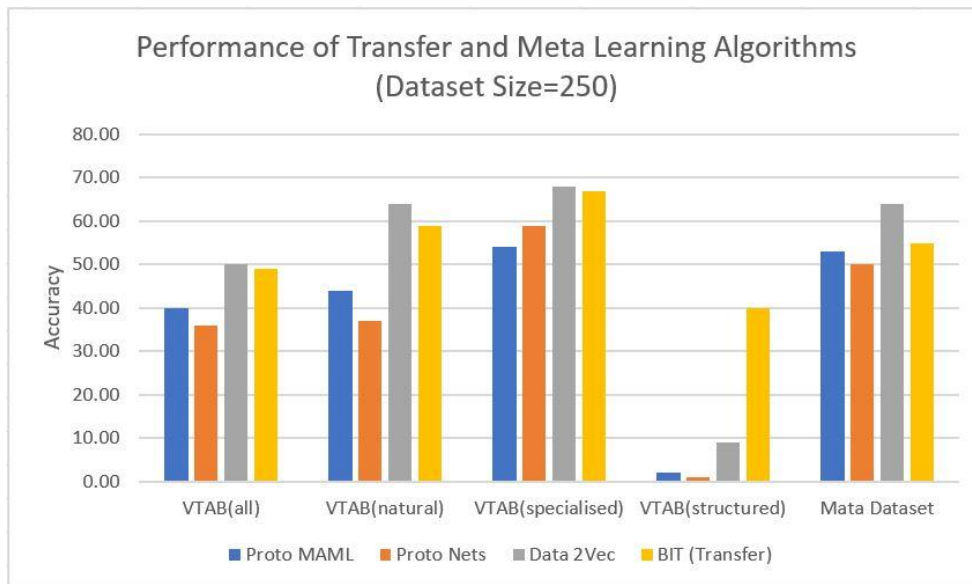


Figure 7 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset when the size of the training dataset is 250 images.

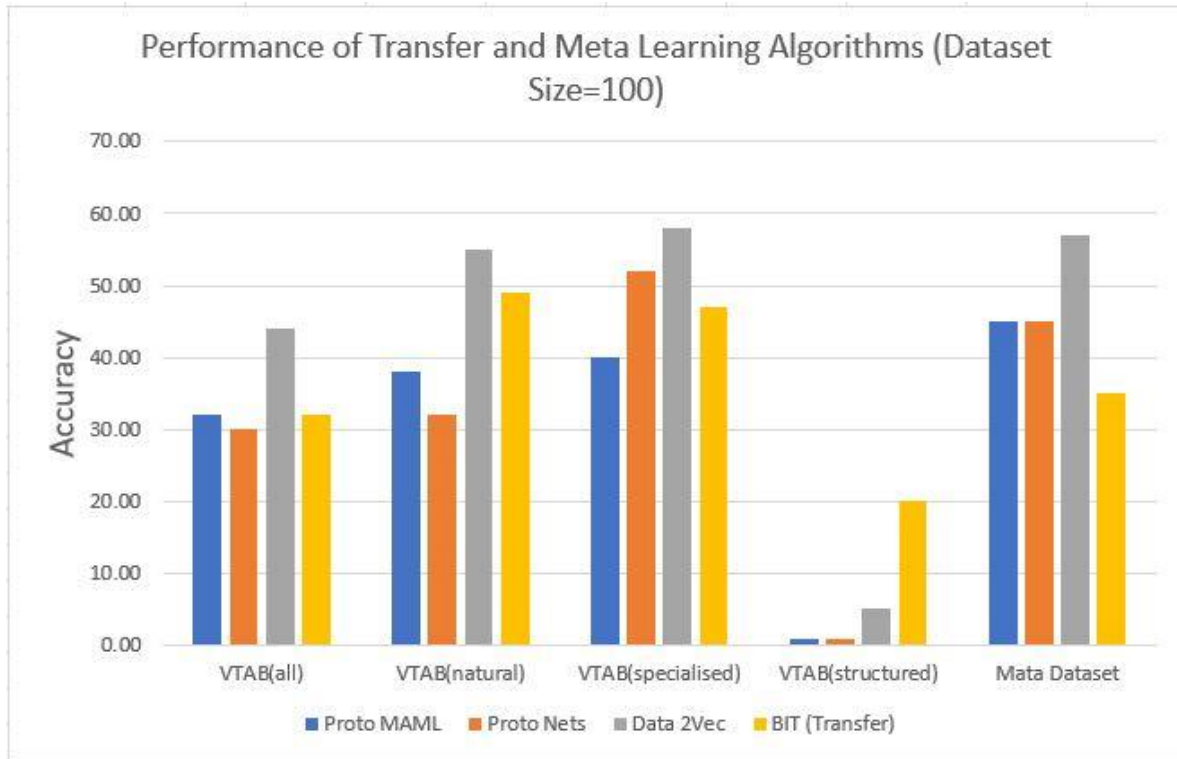


Figure 8 - Results obtained from running transfer and meta learning algorithms against VTAB and Meta Dataset when the size of the training dataset is 100 images.

The results from this experiment were very interesting. When the size of the training dataset was incrementally reduced down to 500, the overall superiority of the transfer method stood ground except against the Meta Dataset which was more suited for meta learning. However, when the size of the dataset was further reduced, meta learning methods, in particular the Data2Vec method outperformed the transfer method even though all methods suffered with the reduction of the size of the training dataset. These results showed that transfer learning methods are more affected by the reduction of the size of the training dataset and meta learning methods are more suited for few-shot learning when the size of the training dataset is very small.

## 5. Conclusions

Throughout the literature review, it became evident that the interest in few-shot learning has surged over the past five years. This surge in interest closely aligns with the burgeoning activity and performance improvements in transfer learning that began around 2015, driven by remarkable achievements in Convolutional Neural Networks leveraging vast datasets. It is conceivable that AI experts recognized the potential of transfer learning to replicate similar successes in domains where data scarcity prevailed. The enthusiasm for meta learning emerged slightly later, with a distinctive focus on achieving robust results for previously unencountered tasks characterised by limited data availability. Meta learning approaches, by their very nature, are more versatile than transfer learning, potentially offering higher utility. Nevertheless,

Dumoulin and colleagues have indicated that they have yet to match the performance of transfer learning methods. However, my results from experiment 1, involving the novel method Data2Vec from MetaAI, suggest that this performance gap is closing. Data2Vec was chosen for this experiment based on its impressive achievements in the area of natural language processing. While there was insufficient time for an in-depth analysis of the reasons behind its superior performance, further examination of this aspect promises valuable insights.

Perhaps the more noteworthy revelation pertains to how both methods respond when the training dataset size is reduced. Despite the prior findings, which suggested that transfer learning necessitates relatively large datasets for effective fine-tuning, my experiment indicated that they require a minimum of approximately 500 training samples. In scenarios where this requirement cannot be met, meta learning emerges as the superior approach.

These observations have contributed to the development of a criterion for selecting the most suitable few-shot learning method under varying circumstances, as graphically depicted in Figure 9. In conclusion, when the original dataset is available and there are ample computational resources and time, the optimal choice is to combine the two datasets. However, in practical scenarios where the original dataset is not accessible, the primary decision criterion becomes dataset size. If the dataset is sufficiently large for fine-tuning, transfer learning stands as the superior choice, provided there exists a meaningful correlation between the original and new tasks. Conversely, when dataset size falls short, meta learning emerges as the preferred alternative. It is important to note that meta learning heavily relies on task correlations, and in their absence, it yields notably subpar results. Thus, to summarise, for few-shot learning tasks, when dealing with a very small new dataset and substantial inter-task correlations, meta learning offers the superior approach.

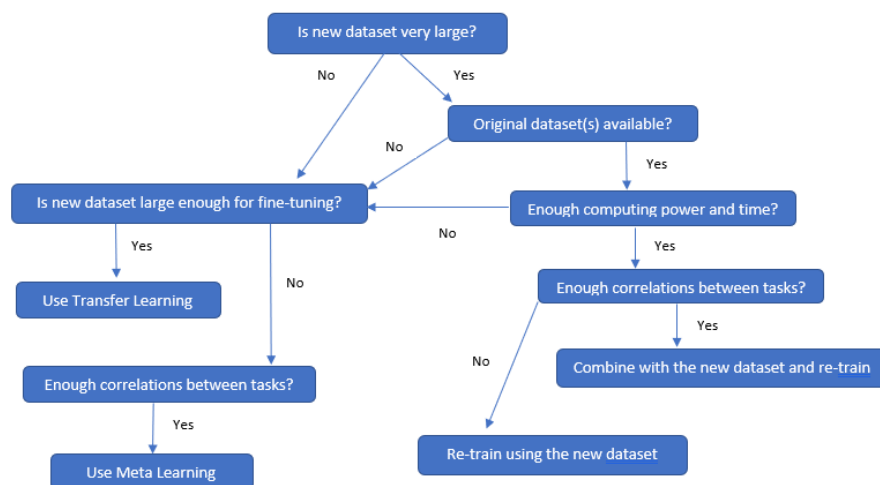


Figure 9 - The decision tree developed in this project to choose between transfer learning and meta learning.

## Works Cited

- Weiss, Karl, Taghi M. Khoshgoftaar, and DingDing Wang. "A survey of transfer learning." *Journal of Big data* 3.1 (2016): 1-40.
- Gilmer, J., et al. "ICML'17: Proceedings of the 34th International Conference on Machine Learning." (2017).
- Dumoulin, Vincent, et al. "A unified few-shot classification benchmark to compare transfer and meta learning approaches." *Thirty-fifth Conference on Neural Information Processing Systems Datasets and Benchmarks Track (Round 1)*. 2021.
- Wang, Yaqing, et al. "Generalizing from a few examples: A survey on few-shot learning." *ACM computing surveys (csur)* 53.3 (2020): 1-34.
- Albawi, Saad, Tareq Abed Mohammed, and Saad Al-Zawi. "Understanding of a convolutional neural network." *2017 international conference on engineering and technology (ICET)*. Ieee, 2017.
- Simonyan, Karen, and Andrew Zisserman. "Very deep convolutional networks for large-scale image recognition." *arXiv preprint arXiv:1409.1556* (2014).
- He, Kaiming, et al. "Deep residual learning for image recognition." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2016.
- Stanford "Transfer & Meta-Learning." Deep Multi-task & Meta Learning ( 2020 ) Lecture 3. Stanford CS330, Feb. 2022.
- Kolesnikov, Alexander, et al. "Big transfer (bit): General visual representation learning." *Computer Vision—ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part V 16*. Springer International Publishing, 2020.
- Li, Yaliang, et al. "Automl: From methodology to application." *Proceedings of the 30th ACM International Conference on Information & Knowledge Management*. 2021.
- "Transfer & Meta-Learning." Deep Multi-task & Meta Learning ( 2020 ) Lecture 4. Stanford CS330, Feb. 2022.
- Huisman, Mike, Jan N. Van Rijn, and Aske Plaat. "A survey of deep meta-learning." *Artificial Intelligence Review* 54.6 (2021): 4483-4541.
- Melekhov, Iaroslav, Juho Kannala, and Esa Rahtu. "Siamese network features for image matching." *2016 23rd international conference on pattern recognition (ICPR)*. IEEE, 2016.
- Snell, Jake, Kevin Swersky, and Richard Zemel. "Prototypical networks for few-shot learning." *Advances in neural information processing systems* 30 (2017).
- Zhou, Jie, et al. "Graph neural networks: A review of methods and applications." *AI open* 1 (2020): 57-81.
- Hu, Han, et al. "Local relation networks for image recognition." *Proceedings of the IEEE/CVF International Conference on Computer Vision*. 2019.
- Liu, Hao, Richard Socher, and Caiming Xiong. "Taming maml: Efficient unbiased meta-reinforcement learning." *International conference on machine learning*. PMLR, 2019.



- Nichol, Alex, and John Schulman. "Reptile: a scalable meta learning algorithm." *arXiv preprint arXiv:1803.02999* 2.3 (2018): 4.
- Li, Zhenguo, et al. "Meta-sgd: Learning to learn quickly for few-shot learning." *arXiv preprint arXiv:1707.09835* (2017).
- Baevski, Alexei, et al. "Data2vec: A general framework for self-supervised learning in speech, vision and language." *International Conference on Machine Learning*. PMLR, 2022.
- Chen, Wei-Yu, et al. "A closer look at few-shot classification." *arXiv preprint arXiv:1904.04232* (2019).
- Zhai, Xiaohua, et al. "A large-scale study of representation learning with the visual task adaptation benchmark." *arXiv preprint arXiv:1910.04867* (2019).

# A CNN-based Approach to Classify Everyday Screws in Real-world Scenarios By Kaartik Tejwani

## Abstract

With the rise of DIY and home improvement, the correct identification and use of screws can often prove challenging for novice consumers. This investigation revolves around the introduction of three novel images datasets of screws and leverages Convolutional Neural Networks (CNNs) to identify them. Although similar research exists from an industrial perspective, minimal research exists to aid consumers in day-to-day operations. Hence, images were captured using a simple cell phone camera in various environments. The first two datasets focus on screw classification with controlled and varying environments, while the final dataset focuses on identifying screws as damaged or undamaged. Using the TensorFlow and Keras libraries, two CNNs were fitted to the dataset: a basic model and a fine-tuned version of ResNet50v2. Evaluation of these models included a discussion of achieved f1-scores, generation of confusion matrices, and avenues for future research and improvement. Initial results indicate a promising potential for CNNs in this realm, particularly when applied with advanced models and architectures.

*Keywords:* Dataset, Screws, Convolution, Classification

## Introduction

Screws are often a preferred and essential component in most household and construction tasks. However, for a novice, the nuances that distinguish one screw from another can easily blur. This may lead to inappropriate use for certain situations, potentially even compromising the integrity of the work and safety (Hoadley). Due to their widespread use and critical importance in projects, ensuring the correct fastener is used not only impacts convenience but also affects safety and quality assurance.

Historically, the onus has been on the consumer to possess the requisite knowledge or rely on experts to make these distinctions. However, a relatively new innovation, CNNs have already demonstrated strong prowess in image recognition tasks across various domains (LeCun, Bengio, and Hinton) . Furthermore, several studies have been conducted to classify screws and detect defects in industrial settings (Mangold et al.; Chen et al.; Saberironaghi et al.)

As opposed to previous research that might rely on highly industrial environments, specialized equipment, or niche sample sets, this study embraces consumer limitations. By re-creating the many challenges and conditions prerequisite to using image recognition technology in the real-world, such as varying backgrounds, lighting, and limited image quality, the research ensures the developed solution is practical, relevant, and accessible to the everyday user.

## Relevant Work

With new image processing techniques emerging such as CNNs, there have been substantial advances in both product categorization and manufacturing. One promising area of study within this scope is the identification of various fasteners and screws, especially considering their essentially ubiquitous use in many products. Several studies have begun exploring this domain, albeit with differing foci.

Mangold et al. (2022) demonstrate a vision-based screw head detection system; the underlying premise of their work is facilitating the identification and subsequent extraction of screws during product remanufacturing processes. Through a variety of image preprocessing and deep learning models, they were able to pinpoint various screw head types with a high degree of accuracy. Similarly, Xiao et al. (2021) attempted to solve the problem of missing small fastener detection using deep learning techniques. On a large-scale manufacturing process, their work spotlighted the challenges associated with identifying small and often overlooked fasteners. However, they still achieved high detection rates of these tiny yet critical components, demonstrating the flexibility and power of CNNs.

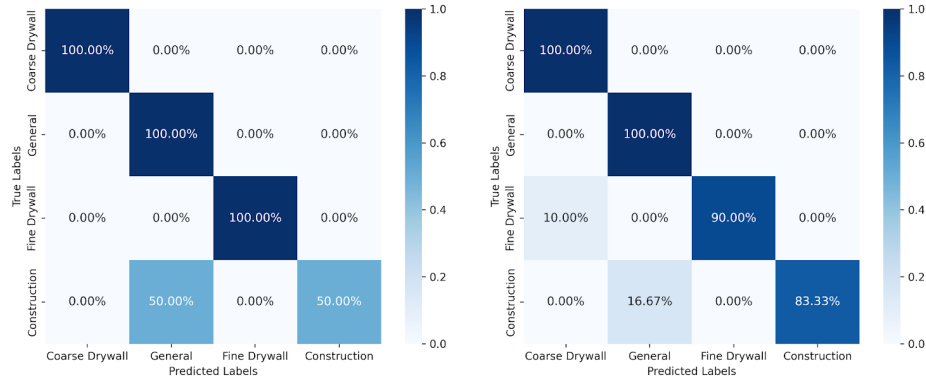
These studies have significantly advanced our understanding of screw and fastener detection using deep learning, but the consumer lens remains largely unexplored in these works, underscoring the motivations for this research.

## Results and Discussion—Dataset One

In general, ResNet50v2 significantly outperformed the basic model, as can be seen in Table 1. Although the basic model achieved a greater f1-score in Coarse Drywall and Fine Drywall screws, it was unable to accurately differentiate between general and construction screws. The confusion matrix for this model, illustrated in Figure 1, reveals that exactly half of the construction screws were predicted as general screws. This misclassification may stem from the similarity in coloring between general and construction screws, or it may indicate overfitting to certain background details. In contrast, the fine-tuned ResNet50v2 achieved a f1-score exceeding 0.9 for all categories, including general and construction screws. An interesting observation arises from the ResNet50v2 confusion matrix, where occasional misclassifications of construction screws as general screws persist—consistent with the basic model's behavior.

Dataset One		
	Basic Model - f1-score	ResNet50v2 - f1-score
Coarse Drywall	1	0.92
General	0.67	0.92
Fine Drywall	1	0.95
Construction	0.72	0.91
weighted avg	0.82	0.92

**Table 1.** Resulting f1-scores for Dataset One using both the basic and fine-tuned models.



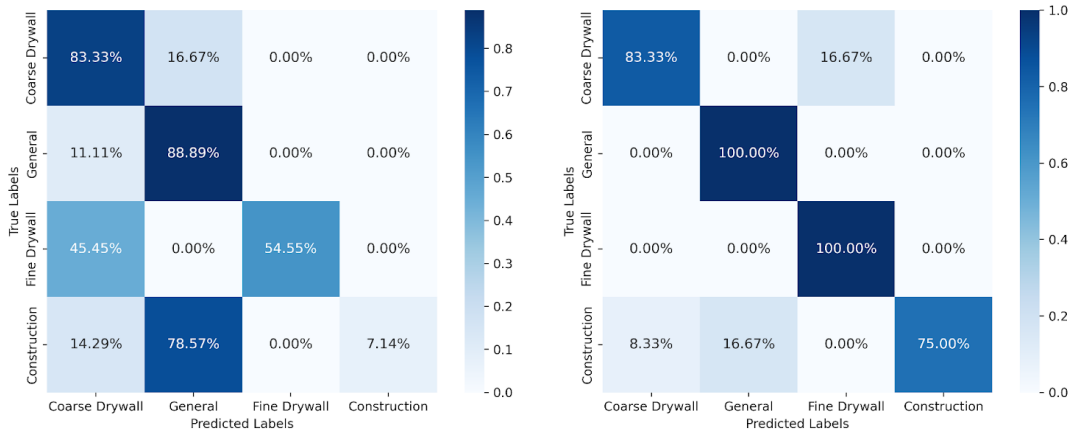
**Figure 1.** The image shows the confusion matrices for Dataset One, the left represents the basic model and the right represents the fine-tuned ResNet50v2 model.

### Dataset Two

As can be seen in Table 2, once again, the fine-tuned model demonstrated a much stronger performance than the basic model for Dataset Two. The basic model seemed unable to adjust to diverse backgrounds, as evident from the weighted average f1-score of merely 0.44. On the other hand, ResNet50v2 was able to correctly predict the class of screws, even with the changing environment. This versatility of ResNet50v2 might be attributed to its significantly larger size, housing 60% more parameters than the basic model. It should be mentioned that there was a small decrease in performance when compared to Dataset One. In particular, the f1-score of coarse drywall screws was noticeably lower. However, the weighted average f1-score remains at 0.9 indicating, with further training and a larger database, higher scores could be achieved. The occasional misclassification of construction screws as general screws is still present in ResNet50v2's confusion matrix, as seen in Figure 2. The basic model's poor performance is reflected in its confusion matrix.

Dataset Two		
	Basic Model - f1-score	ResNet50v2 - f1-score
Coarse Drywall	0.53	0.83
General	0.13	0.92
Fine Drywall	0.71	0.95
Construction	0.55	0.86
weighted avg	0.44	0.9

**Table 2.** Resulting f1-scores for Dataset Two using both the basic and fine-tuned models.



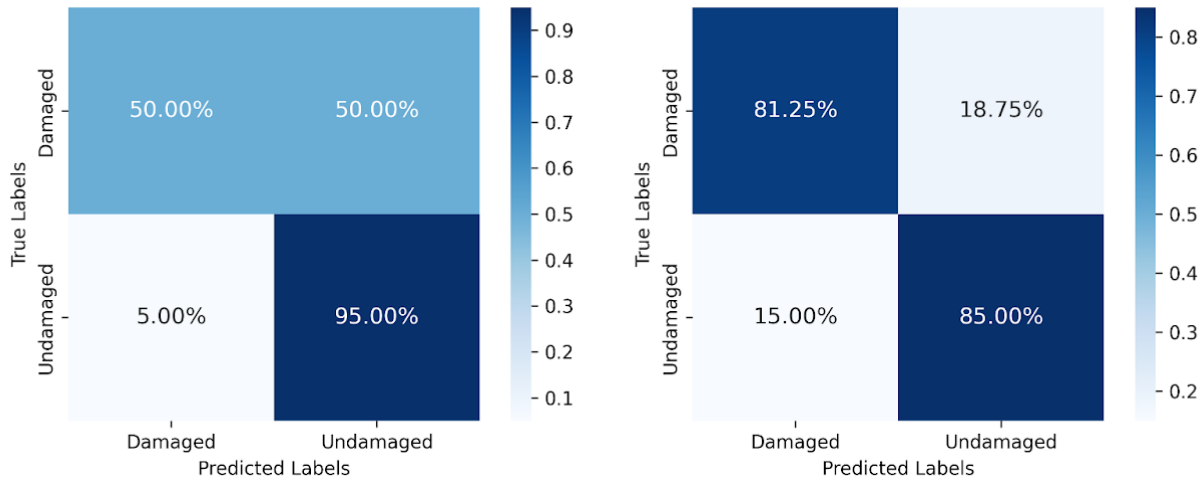
**Figure 2.** The image shows the confusion matrices for Dataset Two, the left represents the basic model and the right represents the fine-tuned ResNet50v2 model.

### Dataset Three

Although the initial fine-tuned ResNet50v2 model excelled in screw classification, it struggled to accurately detect defective screws. This is evident from Figure 3, which demonstrates a bias towards predicting undamaged screws—half of the damaged screws were wrongly identified as undamaged. Consequently, the f1-scores were relatively low, with a weighted average f1-score of 0.73 visible in Table 3. However, the introduction of an L2 weight regularizer significantly improved the model, elevating the weighted average f1-score to 0.83. This indicates that the regularizer reduced the model's reliance on specific features, allowing more subtle features to contribute to predictions (Ng). Additionally, the balanced predictions observed in the confusion matrix suggest that the bias towards undamaged screws was mitigated.

Dataset Three (Base Model Resnet50v2)		
	No Regularizer - f1-score	L2 Regularizer - f1-score
Damaged	0.64	0.81
Undamaged	0.81	0.85
weighted avg	0.73	0.83

**Table 3.** Resulting f1-scores for Dataset Three. The table compares the use of an L2 regularizer on the fine-tuned model.



**Figure 3.** The image shows the confusion matrices for Dataset Three with ResNet50v2, the right represents no regularizer while the left represents L2 regularizer.

### Future Research

To gain insights into the models’ decision making, future research should incorporate the use of feature visualization and attention maps, like Grad-CAM (Selvaraju et al.). This deeper understanding will eliminate the possibility of overfitting to background details and may expose the reason behind the misclassification between general and construction screws. Exploring other sophisticated neural architectures such as Xception, MobileNet, and VGG-19 may also be a beneficial avenue for future endeavors (Chollet; Howard et al.; Simonyan and Zisserman). Most importantly, however, larger datasets using the top screw manufacturers should be created, allowing further flexibility in the models. Another approach could be to create a dataset based on physical specifications such as threads per inch, pitch, and length. This dataset could match any screw with a profile based on these specifications, potentially allowing models to identify any class of screw, even those not found in the database. However, such a dataset may not be usable in varying environments due to inconsistency in image focus and size.

### Methods–Dataset & Screws

For this paper, three datasets encompassing four distinct classes of screws manufactured by GripRite were gathered; each dataset serves a specific purpose for training and evaluating the models. The general specifications for screw types in this study are outlined in Table 4.

Construction	General	Coarse Drywall	Fine Drywall
Grip Rite #8 x 2" Construction Screws	Grip Rite #6 x 2" General Purpose Screws	Grip Rite #6 x 2" Drywall Screws(Coarse)	Grip Rite #6 x 2" Drywall Screws(Fine)

T-25 Star Drive	#2 Phillips Drive	#2 Phillips Drive	#2 Phillips Drive
Coarse Auger Thread	Coarse Thread	Coarse Thread	Fine Thread
Type 17 Point	Sharp Point	Sharp Point	Sharp Point
Yellow Zinc Plated	Yellow Zinc Plated	Phosphate Coated	Phosphate Coated

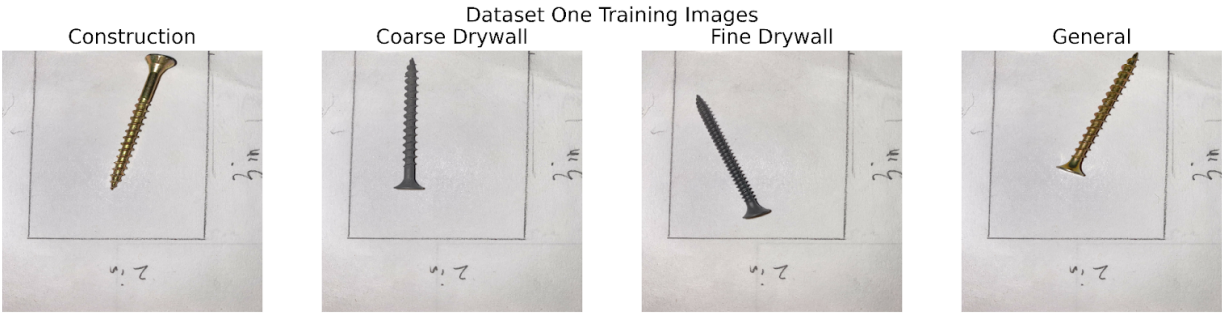
**Table 4.** Outlines characteristics for each screw class. Photography Set Up

To mirror real-world conditions faced by consumers, a common cell phone camera was used without any external lighting. All images were captured using the wide lens of an iPhone 11 Pro configured to 0.7+ exposure, flash, and other default settings. The camera remained consistently positioned 3.25 inches away from the screw, assisted by a small wooden jig for stability, as illustrated in Figure 4. A total of 680 images were captured for model training. Before model fitting, images were rescaled to 512x512 pixels and organized into batches of sixteen. The training dataset comprised eighty percent of the images, with the remaining were used for validation.



**Figure 4.** Set up used to capture images.  
Dataset One: Controlled Settings

The initial dataset, Dataset One, comprises 200 images categorized into four classes: Coarse Drywall, Fine Drywall, General, and Construction screws. Each screw was positioned within a standardized 2"x3" box on a white sheet of paper. To ensure diversity, ten unique samples of each screw type were captured, each photographed from five randomly selected orientations. Dataset One evaluates the model's consistency in recognizing screws under controlled conditions.



**Figure 5.** Sample images from Dataset One.

**Dataset Two: Varied Backgrounds**

Dataset Two consists of 200 images spanning the same four screw classes. However, in this case, screws were placed against diverse backgrounds under varying lighting conditions. These backgrounds include surfaces such as a garage floor, concrete sidewalk, wooden table, kitchen countertop, and cardboard box. This Dataset aims to test the model's ability to accurately identify screws amidst varying backgrounds.

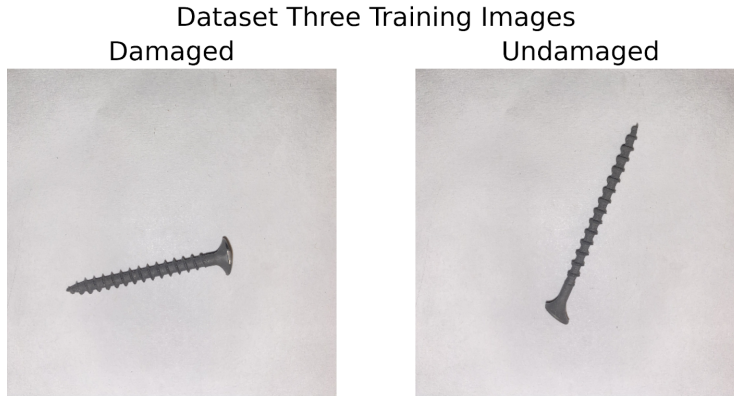


**Figure 6.** Sample images for Dataset Two

**Dataset Three: Defect Detection**

Dataset Three addresses defect detection, focusing exclusively on Coarse Drywall screws. This dataset comprises 180 images, half of which showcase screws with distinct defects. Some example defects include deformed heads, shanks, threads, blunt tips, and corrosion. These effects were simulated using common tools along with a corrosive mixture of hydrogen peroxide and vinegar. The objective of creating Dataset Three is to assess the model's efficacy in identifying damaged screws.





**Figure 7.** Sample images for Dataset Three

### Models

Data augmentation techniques and machine learning models were implemented using the TensorFlow and Keras libraries. The evaluation focused on two models: a 'basic model' and a fine-tuned version of the ResNet50v2 architecture (He et al.). The architecture of the basic model involves a sequence of convolutional and pooling layers designed to extract features from images. The model comprises a total of 16,244,388 parameters and has four potential output classes. In contrast, the fine-tuned model builds upon the pre-trained ResNet50v2 model, additional layers include a dense layer and a dropout layer. These layers are integrated to adapt the model for four-class classification. The overall model comprises 26,130,925 parameters, with 515,076 trainable parameters tailored to the specific classification task. The majority of parameters (25,615,849) remain unaltered from the original pre-trained ResNet50v2 architecture. Table 2 outlines specific output shapes for each layer in the models.

<b>Basic Model</b>		<b>Fine-tuned Resnet50v2</b>	
Layer Type	Output Shape	Layer Type	Output Shape
Conv2D	(None, 512, 512, 16)	InputLayer	(None, 512, 512, 3)
MaxPooling2D	(None, 256, 256, 16)	KerasLayer(ResNet50v2)	(None, 1001)
Conv2D	(None, 256, 256, 32)	Dense	(None, 512)
MaxPooling2D	(None, 128, 128, 32)	Dropout	(None, 512)
Conv2D	(None, 128, 128, 64)	Dense	(None, 4)

Basic Model		Fine-tuned Resnet50v2	
MaxPooling2D	(None, 64, 64, 64)		
Flatten	(None, 262144)		
Dense	(None, 128)		
Dense	(None, 4)		

**Table 5.** Summary of layers and output shape for each model.

### Experiments & Evaluation Metrics

The basic model employs the Adaptive Moment Estimation ('adam') optimizer to ensure the fastest convergence (Kingma and Ba). The fine-tuned model, due to its complexity, utilizes the Root Mean Square Propagation ('RMSprop') optimizer instead ("Lecture 6e: Rmsprop"). Models were trained to convergence, or for at least 100 epochs. Notably, the basic model was not applied to Dataset Three due to poor results. Instead, experimentation for Dataset Three involved the incorporation of an L2 weight regularizer with the fine-tuned model to improve outcomes. Owing to differences in classification types (binary vs. multi-class), Datasets One and Two utilized categorical cross-entropy loss functions, while Dataset Three deployed binary cross-entropy (Goodfellow, Bengio, and Courville).

Throughout the training, the validation loss function and accuracy were monitored for each epoch. After training, various metrics were calculated for each class, including f1-score, recall, precision, and the generation of confusion matrices. The f1-score is a widely adopted performance metric, and serves as a strong measure of model accuracy, taking both precision and recall into account (Sokolova and Lapalme). Computed as the harmonic mean of these two indicators, the f1-score offers a balanced perspective on a model's ability to correctly classify instances while minimizing false positives and negatives. Confusion matrices offer insights into the model's predictions and tendencies. This can provide insight into potential biases. Together, these elements offer an adequate evaluation of the models' performance across various classes and datasets.

### Conclusion

This paper introduces novel datasets that were designed to represent real-world scenarios from a consumer standpoint. By ensuring that images were collected with commonly available equipment and on a variety of backgrounds, the datasets test the capability of CNNs for this task. The high f1-scores achieved prove the viability of CNNs, especially when leveraging fine-tuned existing models, to correctly predict different types of screws from images. This has direct implications for consumer convenience and safety, ensuring that individuals can make informed decisions about screw types, even if they lack specialized knowledge. Additionally, evaluated

models show that they may also be able to flag defective screws, adding another layer of utility and quality assurance. Future research may want to explore the creation of larger and more flexible dataset or enhanced models.

### **Acknowledgments**

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## Works Cited

- Hoadley, R. B. *Joining Wood. In Understanding Wood: A Craftsman's Guide to Wood Technology. Essay.* Taunton Press, 2017.
- LeCun, Yann, et al. 'Deep Learning'. *Nature*, vol. 521, no. 7553, Springer Science and Business Media LLC, May 2015, pp. 436–444, <https://doi.org/10.1038/nature14539>.
- Mangold, Simon, et al. 'Vision-Based Screw Head Detection for Automated Disassembly for Remanufacturing'. *Procedia CIRP*, vol. 105, Elsevier BV, 2022, pp. 1–6, <https://doi.org/10.1016/j.procir.2022.02.001>.
- Chen, Wei-Yu, et al. 'Real-Time Instance Segmentation of Metal Screw Defects Based on Deep Learning Approach'. *Measurement Science Review*, vol. 22, no. 3, Walter de Gruyter GmbH, June 2022, pp. 107–111, <https://doi.org/10.2478/msr-2022-0014>.
- Saberironaghi, Alireza, et al. 'Defect Detection Methods for Industrial Products Using Deep Learning Techniques: A Review'. *Algorithms*, vol. 16, no. 2, MDPI AG, Feb. 2023, p. 95, <https://doi.org/10.3390/a16020095>.
- Xiao, Ling, et al. 'Missing Small Fastener Detection Using Deep Learning'. *IEEE Transactions on Instrumentation and Measurement*, vol. 70, Institute of Electrical and Electronics Engineers (IEEE), 2021, pp. 1–9, <https://doi.org/10.1109/tim.2020.3023509>.
- Ng, Andrew Y. 'Feature Selection, L1 vs. L2 Regularization, and Rotational Invariance'. *Twenty-First International Conference on Machine Learning - ICML '04*, ACM Press, 2004, <https://doi.org/10.1145/1015330.1015435>.
- Chollet, Francois. 'Xception: Deep Learning with Depthwise Separable Convolutions'. *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, IEEE, 2017, <https://doi.org/10.1109/cvpr.2017.195>.
- Howard, Andrew G., et al. 'MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications'. *arXiv [Cs.CV]*, 16 Apr. 2017, <http://arxiv.org/abs/1704.04861>.
- Simonyan, Karen, and Andrew Zisserman. 'Very Deep Convolutional Networks for Large-Scale Image Recognition'. *arXiv [Cs.CV]*, 4 Sept. 2014, <http://arxiv.org/abs/1409.1556>. arXiv.
- He, Kaiming, et al. 'Identity Mappings in Deep Residual Networks'. *Computer Vision – ECCV 2016*, Springer International Publishing, 2016, pp. 630–645, [https://doi.org/10.1007/978-3-319-46493-0\\_38](https://doi.org/10.1007/978-3-319-46493-0_38). Lecture Notes in Computer Science.
- Kingma, Diederik P., and Jimmy Ba. 'Adam: A Method for Stochastic Optimization'. *arXiv [Cs.LG]*, 22 Dec. 2014, <http://arxiv.org/abs/1412.6980>. arXiv.
- Kim, Blitz. *Lecture 6E : Rmsprop: Divide the Gradient by a Running Average of Its Recent Magnitude*. Youtube, 8 Dec. 2016, [https://www.youtube.com/watch?v=SJ48OZ\\_qlrc](https://www.youtube.com/watch?v=SJ48OZ_qlrc).
- Goodfellow, Ian, et al. *Deep Learning*. Alanna Maldonado, 2023.
- Sokolova, Marina, and Guy Lapalme. 'A Systematic Analysis of Performance Measures for Classification Tasks'. *Information Processing & Management*, vol. 45, no. 4, Elsevier BV, July 2009, pp. 427–437, <https://doi.org/10.1016/j.ipm.2009.03.002>.

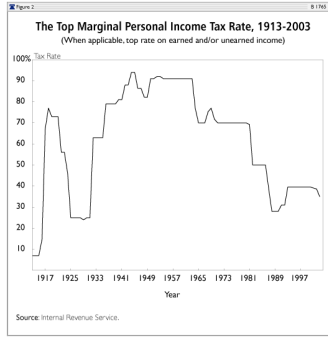
## **America in the 1980s through Punk and American Psycho: Greed, Conformity, and Hyperconsumption By Deaclan Meehan**

In the 1980s—particularly in major cities such as New York City—neoliberal politics resulted in corporate policies that challenged Americans’ ability to empathize and cultivate meaningful relationships with others. Ronald Reagan’s economic policies, known as “Reaganomics,” eroded social safety nets while increasing corporate profits and economic inequality. As we navigate increased political polarization, acknowledging and understanding the socio-economic implications of Reagan’s presidency is crucial. Bret Easton Ellis’s 1991 novel *American Psycho* (as well as Mary Harron’s 2000 film adaptation) embodies the era’s worst traits in their most extreme form through its protagonist Patrick Bateman, a Wall Street serial killer. *American Psycho* is displeasing—it is filled with laundry lists of consumer brands, remorseless murder, and extreme misogyny and racism.<sup>1</sup> Although some critics suggested that the book was too explicit to warrant academic discussion, Ellis made *American Psycho* overtly offensive precisely to illuminate the problems of the 1980s and the extent to which they went unchecked.

If the public reception of *American Psycho* highlighted the severity of the cultural crisis, the Punk Rock movement underscored its insidiousness. Punk emerged in the early 1980s as a reaction to an American culture that some thought was dangerously shallow. However, the movement eventually came to embody the same obsession with image they had tried to fight against, a paradoxical reality that reflected how deeply rooted the problem was. As *American Psycho* and the rise and fall of the Punk Rock movement show, Reagan’s two terms (1981-1989) served as a catalyst for detrimental cultural changes, including a shift towards greed, hyperconsumption, conformity, and *serial substitution*, the reverberations of which America continues to experience today.

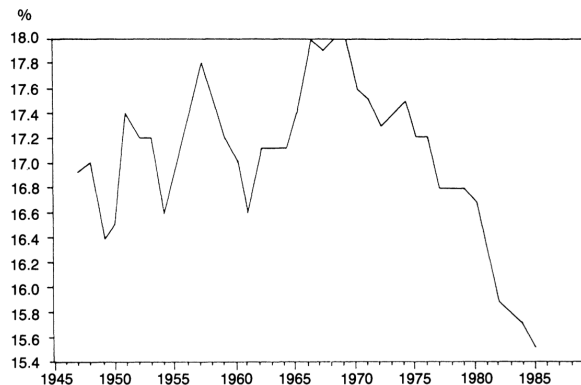
### **The Implementation of Reaganomics**

The implementation of Reaganomic neoliberal policies significantly exacerbated income inequality. Neoliberalism is an economic ideology that values free-market competition—that is, minimal government intervention in economic and social affairs.<sup>2</sup> Reagan’s policies promoted “trickle-down economics,” a neoliberal theory positing that tax cuts for the wealthy benefit society as a whole by stimulating economic growth. The Economic Recovery Tax Act of 1981 and the Tax Reform Act of 1986 embodied trickle-down economics. Together, these laws provided tax relief to businesses while lowering the top marginal tax rate from 50% to 28% (Figure 1).<sup>3</sup> The benefits for the rich were substantial: a higher earner paying \$700,000 in taxes a year in the 1970s saw their taxes cut to \$350,000 in the 1980s.<sup>4</sup> Meanwhile, the Standard and Poor’s index (S&P 500) increased 113.3% under Reagan, compared to 10.4% during the preceding 2,024 trading days, an economic outcome that predominantly benefited those with capital to invest.<sup>5</sup>

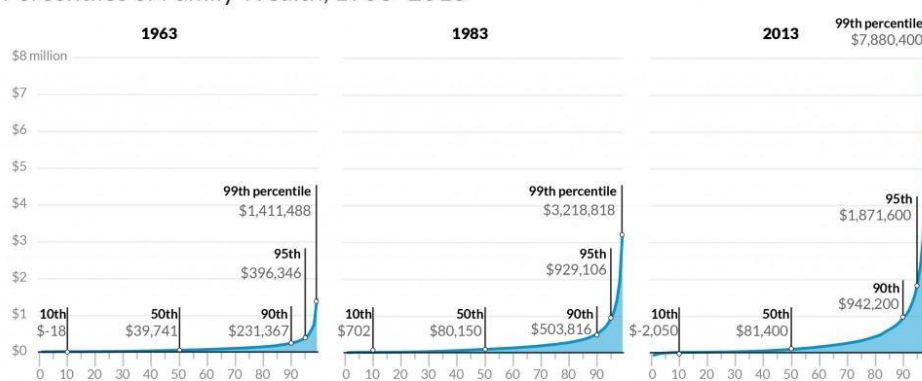


**Figure 1:** The Top Marginal Personal Income Tax Rate

The promised effects of Reaganomics never reached the lower classes. The “trickle” instead “had the viscosity of molasses and stuck with the ultrarich.”<sup>6</sup> While the income of the top one percent of earners rose from nine percent of total American income in 1979 to a peak of fourteen percent in 1986, the bottom ninety percent of earners saw a lower share of total income in 1989 compared to 1979.<sup>7</sup> This grave reality for average Americans was exacerbated by the fact that, in an effort to balance the lost income from lowered tax rates, Reagan cut substantial funding from social services, including welfare benefits, further increasing economic inequality throughout the 1980s (Figure 2).<sup>8</sup> Cuts to social services were not only detrimental, but also ineffective: the federal budget deficit rose dramatically during Reagan's administration, from \$79 billion in 1981 to \$221 billion in 1986.<sup>9</sup> Although economic inequality surged during Reagan's tenure, these economic imbalances continued after he left office, underscoring the enduring impact of his policies and the sustained influence of neoliberal ideology within American society (Figure 3).<sup>10</sup> The CEO-to-worker compensation ratio mirrored larger trends in inequality, growing in the 1980s through the 1990s, when it “exploded.”<sup>11</sup> Reaganomics promised prosperity for all, but ultimately led to an economy that disproportionately favored the elite.



**Figure 2:** Share of bottom 40 percent of aggregate family income

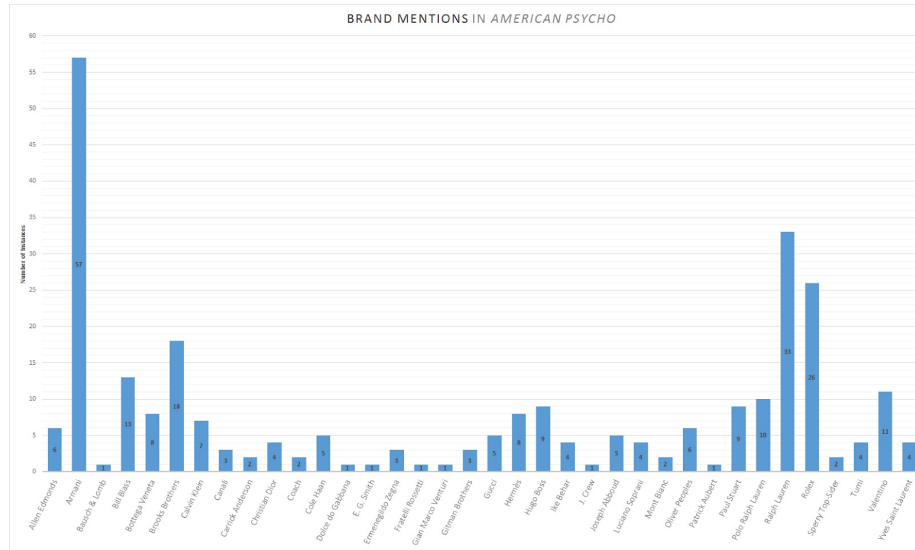


**Figure 3:** Percentiles of Family Wealth, 1963-2013 Societal Shifts: Consumerism, Conformity, and Overconsumption

### *The Rise of Consumerism*

Neoliberal economic policies laid the groundwork for an escapist culture deeply rooted in obsessive consumerism, a phenomenon Ellis highlights in *American Psycho*. The novel follows Patrick Bateman, a 27-year-old Harvard graduate working on Wall Street in the 1980s. Bateman, a young, good-looking, white, cisgender Republican, embodies consumer culture, wielding a platinum Amex card and obsessing over Donald Trump.<sup>12</sup> His relentless pursuit of conformity, an attractive outward appearance, and material goods leaves him feeling hollow and ultimately drives him to commit numerous acts of extreme violence, including murder, rape, torture, and cannibalism. The novel's depictions of rampant consumerism and narcissistic obsessions forces the reader to "look squarely at the horrific lived reality of late capitalist America."<sup>13</sup> Ellis uses Bateman's character to critique the pervasive consumerism of the 1980s, illustrating how living in a society that measures worth in terms of wealth is self-destructive, even for the most successful, like Patrick Bateman.

The significant shifts in economic conditions throughout the 1980s enabled a surge of overconsumption and materialism among a demographic called "yuppies." The term "yuppie," short for "young urban professional," became a buzzword of the era.<sup>14</sup> It defined a group of young, well-educated, high-income earners who were drawn to the lifestyle offerings of urban environments and embodied the consumeristic zeitgeist.<sup>15</sup> Their professional success provided them with substantial disposable income, which they eagerly spent on status symbols: luxury cars, designer clothing, and high-end consumer electronics.<sup>16</sup> Yuppies also wanted others to see them with these products in prestigious settings.<sup>17</sup> Ellis depicts Patrick Bateman as the ultimate yuppie consumer. Throughout the novel, he constantly preoccupies himself with his own and other's wealth—their clothes, accessories, and even toiletries (Figure 4).



**Figure 4:** Mentions of Brand Names in American Psycho

Bateman's fixation on brands is not merely a personal quirk; it serves as a microcosm of the broader societal obsession with brand names and the status they conferred. From Rolex watches to Armani suits, yuppies sought to buy “tickets” to an exclusive club only accessible to the wealthy. The societal fixation on markers of affluence revealed the rise of a new paradigm of consumption fueled by a relentless pursuit of prestige and a propensity to overindulge. Reaganomics’s benefits for the wealthy caused this shift and the rise of the yuppie. However, instead of further trickling down, yuppie spending patterns had a negative effect on the middle class. Because their spending habits and lifestyle choices largely dictated the consumer trends of the 1980s, the media made their lifestyles the “ideal,” bombarding the middle class with images of this luxury and opulence that were largely unattainable to them. These portrayals of wealth significantly influenced the consumption patterns of the middle class, creating a sense of dissatisfaction with their own living standards and prompting them to strive for a lifestyle beyond their means, a shift from the media’s traditional content.

### *The Drive to Conform*

Exposure to the media profoundly impacted American spending in the 1980s. Prior to the 1980s, media and popular culture often centered around the standard, middle-class American consumer who wanted to keep up with their neighbor, the “Joneses.”<sup>18</sup> However, throughout the 1980s, these patterns shifted: television shows and advertisement began to amplify the visibility of upper-class lifestyles like Patrick Bateman’s, thereby influencing societal values and spending patterns. Not only did Americans spend more as they aspired to keep up with the higher classes, but those who watched large amounts of television were driven to consume more because the media warped their sense of typical consumption, convincing them that luxury items affordable only to the ultrarich were relatively commonplace and, therefore, reasonable aspirations for them.<sup>19</sup> Conspicuous consumption, purposely purchasing goods or services to display one's



wealth, became a predominantly middle-class phenomenon as consumers grew to believe that the status of goods confirmed a person's social position. Despite there being only around 4.6 million “yuppies” in the 1980s, studies found that over thirty-five million baby boomers shopped with the same mindset.<sup>20</sup> Middle-class Americans were acquiring luxury goods at a greater rate than any previous generation of the middle class.

Shame over financial insecurities also drove middle-class consumption. As Reaganomics lined the pockets of the upper class, middle-class professionals faced slow job mobility, competition in the job market, a sagging middle-class economy, and a decline in real income. Many baby boomers tried to subdue their hopelessness with the gratification from these status symbols; these consumers purchased items at a clip they could not afford—in the 1980s consumer debt doubled, despite declining real income.<sup>21</sup> The heightened visibility of upper-class lifestyles led to a surge in consumer debt as more people, largely from the middle class, strove to mirror the consumption patterns of the rich. Identifying with unrealistic economic groups led many to spend well above their means, acquiring large debts and suffering frustrations as they attempted to join those groups through their consumption patterns but failed to attain the income needed to sustain themselves.<sup>22</sup> In essence, both the members of the middle and upper class felt strong societal pressures to conform and to demonstrate self-worth in materialistic ways, regardless of whether these objects would make them happy or even if they could afford them.

*American Psycho* provides a vivid depiction of the oppressive standards of conformity in the 1980s, underscoring the societal implications of the economic and cultural forces Reaganism engendered. In one scene, Bateman listens to Huey Lewis and the News’ “Hip to Be Square,” a song emblematic of the 1980s culture of conformity. Almost as an act of defiance against societal conformity and its superficial values, Bateman commits a brutal murder while the song plays in the background. The act’s violence starkly juxtaposes the upbeat tune of the song, exaggeratedly emphasizing the dark psychological effects of societal pressures to fit in. Huey Lewis sings about embracing contemporary trends like eating healthily and exercising, not necessarily for personal wellness, but as a part of societal expectation. The lyrics represent the reality that in the 1980s, many felt maintaining an image was important above all else. In the novel, Bateman candidly reveals his ambitions to his girlfriend, Evelyn, telling her succinctly that he wants “to ... fit ... in.”<sup>23</sup> Ellis demonstrates that the need to conform, stemming from the era's rampant consumerism and the economic policies of Reaganomics, transformed individuals into mere transactions. The pursuit of fitting in leads Bateman to lose his humanity, as he becomes trapped in a ceaseless cycle of consumerism and superficiality.

### *The Long-Term Impacts of Overconsumption*

As American society adopted patterns of overconsumption en masse, certain consumers were left psychologically altered. With a constant demand for more products, the 1980s saw the constant proliferation of new devices like personal computers, videocassette recorders, and mobile communication devices, which all quickly became staples in the average household. At the same time, consumer electronics dominated the decade: the introduction of Sony’s Walkman

transformed the way consumers engaged with music, a shift from LP records to CDs offered superior sound quality and durability, and telephones became more diverse, affordable, and portable. Other electronics, including automatic cameras, microwave ovens, and food processors, saw a surge in popularity.<sup>24</sup> An explosion of styles and technology gave consumers the impression of having more choices and control over their lives, even though most people still fit within a relatively narrow range of trends and preferences.<sup>25</sup> This perceived sense of control not only made buyers consume more, but also fundamentally altered the psyche of the average American by leading to a phenomenon known as “serial substitution.”

In 1986, psychotherapist JoAnn Magdoff coined the term serial substitution to describe an emerging consumer pattern—buying goods and services to change how one looked and felt about oneself.<sup>26</sup> According to Magdoff, serial substitution represented a new reality where individuals could continually reconfigure their self-perception and reality through conspicuous consumption and displaying compelling symbols of economic success, such as cutting-edge technology, fashion, and drugs.<sup>27</sup> A rise in the consumption of “stylish” lifestyle products, such as Swatch watches, hair-styling mousse, and halogen lamps that marked the 1980s also played a significant role in enabling the acts of serial substitution; continuous change in fashion and home furnishing, beyond giving customers a sense of control, also allowed them to overconsume constantly.<sup>28</sup> Shopping became a pastime in which people “grazed” for their next substitution. The decade was also characterized by an explosion of food choices, with more than 112,000 new items gracing supermarket shelves.<sup>29</sup> Key food trends included a focus on fitness, fiber-rich and low-fat foods, fast and easy meals, fresh food sections in supermarkets, single-serving items, gourmet foods, and an increase in foreign or foreign-seeming foods.<sup>30</sup> The decade's food trends oscillated between indulgence and health consciousness, allowing the consumer to constantly alter their self-image while thinking they were changing their routine. In this sense, food was another consumer product—another means of serially substrating—which allowed consumers to escape and re-invent themselves via a purchase.

### **The Punk Revolution Succumbs to Consumerism**

The punk rock culture of the 1980s and 1990s epitomized the extent to which the cultural shifts toward conformity, materialism, and corporatism were entrenched in American society. The 1980s Punk Revolution began as a rebellious subculture opposing the societal changes brought on by Reaganomics and the rise of corporate power. This subculture challenged corporate control of cultural production through self-published “zines” as well as by the creation of networks and platforms for sharing music. The “Do-It-Yourself,” *DIY ethic* was a defining feature of early punk, encouraging young people to rely on local initiative and production, rather than corporations, for creating music and art.<sup>31</sup> Thus, the punk movement was decidedly anti-consumerist and anti-materialist. Because young punks were disillusioned with corporate control of the music industry, they started independent record labels, duplicated cassette tapes, and promoted shows and music through zines and college radio stations. Politics and corporate

culture in the Reagan era fueled this activism, as the youth used cultural outlets to resist both corporate entities in the music world and the conservative political climate of the time.

Punk's opposition to corporate culture extended into political activism, with punks making their music explicitly anti-Reagan and encouraging young adults to get involved in political discourse both inside and outside of the music scene. Bands like the Proletariat, Articles of Faith, Fugazi, Reagan Youth, and others expressed political messages through their lyrics and album liner notes, while groups like the Youth Defense Campaign (YDC) emerged in response to the Seattle police shutting down independent shows.<sup>32</sup> YDC demanded accessible public venues for youth entertainment and blamed entertainment corporations for the crisis in youth entertainment. Positive Force, founded by Nevada teenagers in 1984, collaborated with established nonprofit organizations to educate themselves on political issues and organized meetings, benefit shows, and performances to raise awareness and funds for progressive causes.<sup>33</sup> Meanwhile, the DIY spirit led youth to engage in more spontaneous and aggressive forms of protest, such as "War Chest Tours" and "die-ins." These actions challenged mainstream peace movements and sought to cultivate spontaneity and play in political activism.<sup>34</sup> Youth subcultures participated in various forms of guerrilla-theater style demonstrations, such as "Punk Percussion Protests" against South African apartheid and mock protests against anti-abortion demonstrators. These unconventional protest styles reflected punk culture's aim to disrupt the status quo. The subculture's political outlook centered on a left-leaning anarchism, advocating for decentralized communitarianism and cooperation rather than chaos.<sup>35</sup> By emphasizing lifestyle politics, the Punk movement aimed to empower individuals to protest against social and political problems, particularly the influence of corporate culture on everyday life.<sup>36</sup> The movement peaked between 1984 and 1986, with the formation of Positive Force chapters across the country, popular events like Rock Against Reagan, Alternatives Festival, and benefit concerts for political organizations.

However, as the Punk Revolution gained traction and its music and clothing became more mainstream, the movement's central political themes became diluted. By the late 1980s, the focus had shifted from substance to style, with punk increasingly becoming synonymous with specific haircuts, clothes, and music genres, rather than its underlying philosophy of rebellion and political activism. The corporatization of punk music, especially the rise of alternative rock and the commercialization of punk styles, made the movement paradoxically become what it had rejected. By the late 1980s, the punk movement faced criticism for turning into a fad devoid of meaningful activism, with a growing emphasis on fashion, destructive behavior, and commodification of youth rebellion.<sup>37</sup> Alternative rock's rise and the commercialization of the punk subculture in the late 1980s saw bands like Green Day and Nirvana gain mass popularity and corporate backing.<sup>38</sup> Punk's transformation into a marketable product, one undermining its initial mission against Reaganism and corporate influence, demonstrates the sweeping effects of consumerism and corporatism.<sup>39</sup> By the end of the 1980s, a subgroup emerged whose members dubbed themselves "Punk Reaganites"—young adults who explicitly supported the Reagan administration and its positions, but who dressed in punk styles.<sup>40</sup> "Punk Reaganite" was an oxymoron, but one that was appropriate to the zeitgeist of the 1980s, an era in which

consumerism, materialism, and conformity managed to engulf even the groups that began in fervent opposition to the president whose policy and rhetoric fueled so many of the period's worst traits.

### **Significance in the Modern Day**

The rampant consumerism and materialism that entrenched America's societal fabric throughout the 1980s brought about significant cultural shifts, the consequences of which continue to shape the contemporary political landscape. The 1980s ignited a transformation of societal values that, decades later, continues to influence our understanding and expression of power, wealth, and leadership. Beginning in the early 2000s, figures such as Steve Jobs, Oprah Winfrey, Jeff Bezos, and Elon Musk became prominent not merely through their entrepreneurial success, but through the cults of personality that made them and other CEOs famous and equated wealth with competence. The extreme worship of wealth and power in 1980s culture culminated in this combination of material success with celebrity, which Kanye West's presidential run and Donald Trump's election both reflect. Despite their lack of conventional political credentials, many voters perceived their wealth and fame as markers of competence—status and belongings had surpassed experience as a qualification for leadership. The issues highlighted in Ellis's *American Psycho*, and the punk movement's evolution, have been greatly exaggerated in the modern day. Only by confronting the past can we begin to address the profound implications these shifts have had on our social fabric. Our task, then, is to reassess and redefine the values we hold dear, placing a greater emphasis on empathy, impact, and the intrinsic worth of individuals, as we strive to create a more equitable and compassionate future.

## Works Cited

- Angeli, David H. "A 'Second Look' at Crack Cocaine Sentence Policies: One More Try for Federal Equal Protection." *American Criminal Law Review* 34 (1997): 1211–41.
- Barnett, Steve, and JoAnn Magdoff. "Beyond Narcissism in American Culture of the 1980s." *Cultural Anthropology* 1, no. 4 (1986): 413–24.
- Bivens, Josh, and Jori Kandra. "CEO Pay Has Skyrocketed 1,460% since 1978: CEOs Were Paid 399 Times as Much as a Typical Worker in 2021." Economic Policy Institute, October 4, 2022. <https://www.epi.org/publication/ceo-pay-in-2021/>.
- Brooks, Nancy Rivera. "1980s Shoppers Charged Into a Brave New World of Goods : Consumer Products: Electronic Gadgets, Fitness Fads and Yuppie Indulgences Attracted Attention and Sales during the Past Decade." Los Angeles Times, December 31, 1989. <https://www.latimes.com/archives/la-xpm-1989-12-31-fi-270-story.html>.
- Congressional Budget Office. "The Distribution of Household Income, 2014," March 19, 2018. <https://www.cbo.gov/publication/53597>.
- Creasap, Kimberly. "Punk Politics." *Contexts* 12, no. 1 (2013): 4. <http://www.jstor.org/stable/41960403>.
- Danziger, Sheldon, and Peter Gottschalk. "Increasing Inequality in the United States: What We Know and What We Don't." *Journal of Post Keynesian Economics* 11, no. 2 (1988): 174–95.
- Deaderik, Lisa. "Creating Different Punishments for Crack and Powder Cocaine Never Made Sense, Unscientific." San Diego Union-Tribune, December 25, 2022. <https://www.sandiegouniontribune.com/columnists/story/2022-12-25/sunday-social-justice-updated-federal-guidance-on-ending-drug-sentencing-disparities>.
- Dekker, Paul, and Peter Ester. "The Political Distinctiveness of Young Professionals: 'Yuppies' or 'New Class'?" *Political Psychology* 11, no. 2 (1990): 309–30. <https://doi.org/10.2307/3791692>.
- Ellis, Bret Easton. *American Psycho*. New York: Vintage, 1991.
- Hammond, John L. "Yuppies." *The Public Opinion Quarterly* 50, no. 4 (1986): 487–501
- Harron, Mary, dir. *American Psycho*. 2000; Santa Monica, CA: Lionsgate, 2000. Apple TV.
- Howard, Alexander. "The Case for American Psycho: Why This Controversial Book (Sold Here in Shrink Wrap) Still Matters." *The Conversation*, November 21, 2022. <http://theconversation.com/the-case-for-american-psycho-why-this-controversial-book-sold-here-in-shrink-wrap-still-matters-188463>.
- Komlos, John. "How Reaganomics, Deregulation and Bailouts Led to the Rise of Trump." PBS NewsHour. April 25, 2016. <https://www.pbs.org/newshour/economy/column-how-reaganomics-deregulation-and-bailouts-led-to-the-rise-of-trump>.
- Lowy, Richard. "Yuppie Racism: Race Relations in the 1980s." *Journal of Black Studies* 21, no. 4 (1991): 445–64.
- Mattson, Kevin. "Did Punk Matter?: Analyzing the Practices of a Youth Subculture During the

- 1980s.” *American Studies* 42, no. 1 (2001): 69–97.
- Mitchell, David J. “Historical Lessons of Lower Tax Rates.” The Heritage Foundation. June 19, 1996.  
<https://web.archive.org/web/20070530071923/http://www.heritage.org/Research/Taxes/BG1086.cfm>
- Page, Christine. “A History of Conspicuous Consumption.” *ACR Special Volumes* SV-08 (1992).  
<https://www.acrwebsite.org/volumes/12197/volumes/sv08/SV-08/full>
- Roach, Brian, Neva Goodwin, and Julie Nelson. “Consumption and the Consumer Society.” In *Microeconomics in Context*, Fourth edition. New York: Routledge, 2019
- Smith, Nicola. “Neoliberalism | Definition, Ideology, & Examples.” Britannica, May 18, 2023.  
<https://www.britannica.com/topic/neoliberalism>.
- “SPX | S&P 500 Index Advanced Charting.” The Wall Street Journal. 2003.  
<https://www.wsj.com/market-data/quotes/index/SPX/advanced-chart>.
- Tolson, Arthur L., and Q. R. Hand. “Reaganomics and Black Americans.” *The Black Scholar* 16, no. 5 (1985): 37–49.
- Young, Elizabeth. “The Beast in the Jungle, the Figure in the Carpet.” In *Shopping in Space: Essays on America’s Blank Generation Fiction*, edited by Graham Caveney, 85–122. New York: Atlantic Monthly Pr, 1993.

# The Application of the Engineering Design Process For a Beginner Model Rocket Engineer

## By Satvik Agrawal

### Introduction

Engineering a model rocket can be a difficult process for people who lack experience or are engineering for the first time. There are many steps that need to be fully completed in order to create a final product, and this applies to every product that needs to be engineered. The process of creating a final system is known as the Engineering Design Process, which has seven main steps that need to be cleared in order to create a successful final product. This paper demonstrates an example of a first-time model rocket engineer employing the engineering design process in order to make a model rocket that flies over a 1,000 feet high. The seven main steps of the engineering design process are: defining, asking, imagining, planning, prototyping, testing, and improving (“What is the,” n.d.). The beginner engineer will go through all of these steps in order to create their desired final product.

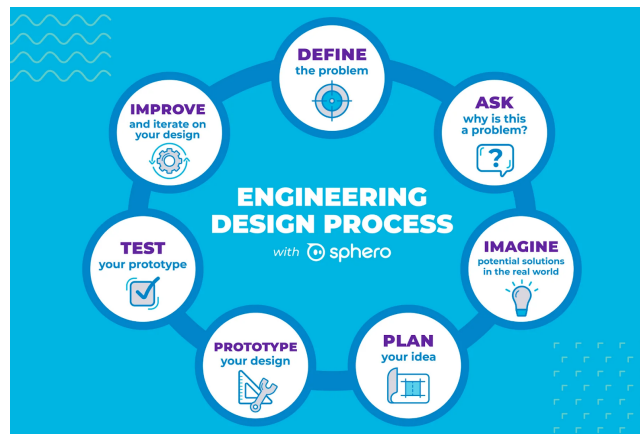


Fig 1: Engineering Design Process Flow

### Conceptual Design

The first step in designing any engineering product is to define the problem. The problem does not need to be anything too sophisticated; it just needs to be an idea that an engineered product can resolve (“What is the,” n.d.). Engineers have to think about the problem and find different ways to interpret it so that finding a solution is easier. This is pivotal, as without a problem, there is no solution, and there needs to be a certain reason for why the product is being made. For example, the beginner engineer has to think about what the problem is, and why they want to make a design system. In his case, the problem is that he has no experience in engineering model rockets, and they want to gain this experience. They can interpret it as a goal or a challenge, but not necessarily as a “problem.” They identify the “problem” and the reason why they want to build their model rocket, and now they are ready to go to the next step.

The second step in the engineering design process is to ask questions about the problem. The questions can be about anything related to the product. For example, engineers can ask how

heavy they want their product to be. They can also ask what material it should be made out of. The identifying of such questions are the basis for creating requirements, which will narrow down the number of solutions to the problem (“What is the,” n.d.). The beginner model rocket engineer needs to think about the fundamentals of their product and brainstorm possible questions. They ask about how heavy the rocket should be. They also ask what kind of safety measures the rocket should have. And perhaps most important, they ask what the rocket should do, what its functionality is. They then compile all of their questions into a list and make them more specific. The engineer is now ready to go to the next step.

The next step is to imagine. This step involves making requirements based off of the questions that were asked in the previous step (“What is the,” n.d.). Requirements are goals that the finished product should accomplish. While the goal is to fulfill every requirement, not every successful project meets all of its requirements; it all depends on the importance of the requirements that are missed. In this project, requirements have five types: functional, performance, physical, safety, and environmental. Functional requirements determine the operation of the finished product. For example, the beginner rocket engineer said that one of the functional requirements is that the system should fly. Another functional requirement is that the system needs to measure the velocity of its flight at all times. Performance requirements set goals for what the system should accomplish. For example, the model rocket engineer wants the system to attain a maximum velocity of at least 100 mph. They also want the system to reach at least 1,000 ft in altitude. Physical requirements set goals for the system’s visual and tangible specifications. For example, the model rocket engineer says that their system’s main body must be made out of PLA, cardboard, or fiberglass. They also maintain that the system’s cost shall not exceed \$100. Safety requirements determine how non-hazardous a product is to people and the environment it may be near or in contact with. For example, the engineer wants their system to not contain any sharp edges. They also do not want the system to use lead-based paint. The last type of requirement, environmental requirements, set goals for how the object should deal with the surrounding conditions and atmosphere it may be subject to (Halligan, 2022). For example, the engineer wants their system to be water-tight to prevent rain intrusion.

This step is not done yet though. Once all the requirements are written, engineers have to label them by their types based on the five categories and also create a numeric system to label them. This makes checking requirements easier. Another step that engineers have to take when making requirements is writing down how they can be tested. In this project, there are three types of testing: inspection, demonstration, and calculation/analysis. Testing by inspection just means using any of the five senses to verify the requirement. For example, the engineer writes down that their requirement for not having any sharp edges in their system can be checked by inspection because they can verify this by just looking at their final product. Testing by demonstration may require some sort of lab or apparatus to be set up in order to verify the requirement. For example, the engineer writes down that their requirement that the system shall fly can be tested by demonstration because they can do a test flight beforehand to check if it flies or not. Testing by calculation means that a calculation can be done to verify the requirement. For



example, the engineer writes down their requirement that the system shall not exceed a cost of \$100, which can be tested by adding the prices of all of the different components the engineer uses to create the system. Once all the requirements are labeled as necessary, the engineer can move on to the next step (Adams, n.d.).

The next step is to plan the design. Engineers now have to determine how they want their design to be made and what they want it to be. They have to narrow down what parts they want their design to consist of and determine which requirements are the most important to their goal. The beginner rocket designer did this by doing a trade study, which involves giving “scores” to alternatives for the same parts. For example, for the main body of the model rocket, they considered three options: fiberglass, cardboard, and PLA. They determined that cardboard fulfills more requirements than the other two materials, so they gave it the highest score for the main body part. This means that their final design will most likely have a main body made out of cardboard. Once this narrowing down has been done for all of the parts of the system, a design can be made (“Systems engineering,” n.d.). The design needs to be detailed, with every part included. It also needs to give the specifications, such as the length and width of parts. Once a design is made, the designer is free to go to the next step: actually creating the design. Figure 2 is the design that the amateur engineer came up with.

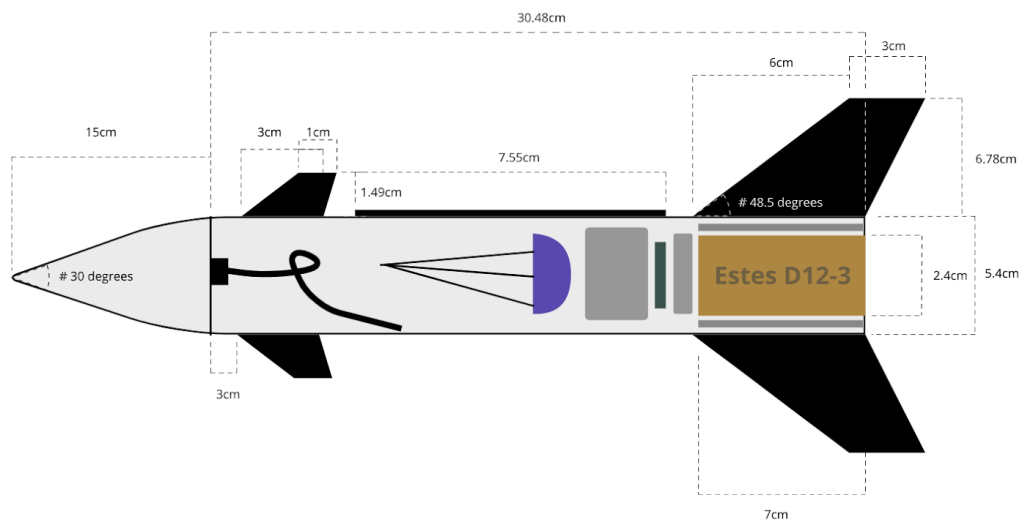


Fig 2: Rocket Conceptual Design with Dimensions

### Building the Rocket

The next step in the engineering design process is to obtain all parts and start the assembly of the system (“What is the,” n.d.). The amateur rocket builder first ordered parts from different websites based on their trade study. In the process though, they spent more than intended on the system, exceeding the budget by about \$50. Once all parts were obtained, the engineer began assembling some of the parts that could be tested individually, such as attaching the nose cone to the shock cord and the parachute. The rest of the rocket could not be built before

launch, though, as the inertial measurement unit and the Arduino would drain the battery before the rocket would be launched. This meant that the rocket had to be fully assembled directly before the launch. This made creating a test plan difficult as some of the testing required the whole rocket to be built before launch.

### Test Plan

When testing a system, an engineer should document three things: the conditions of the testing (setting, people involved, anything else that could affect results), how the test was conducted, and the results of the test. Below in Table 1 are some of the tests that the engineer documented.

Number	Test case	Results	Observation	Conditions
1.1	Flight			
1.2	Measures Velocity	Fail	IMU only measures acceleration, not velocity, but V can be calculated	Drove in car at constant speed
1.3	Measures Altitude	Pass	Measures X, Y and Z position	Dropped from desk and compared initial and final heights
1.4	Contains Parachute	Pass	Rocket built with parachute and shock cord	N/A (Observation)

Table 1: Test Cases

Some of the requirements were not able to be tested though, as they would require the entire system to be built, and for that, the engineer would have to make a replica rocket, which was too outside the budget to execute. This meant that the engineer would just have to wait for launch to see if those requirements were actually met or not.

### Testing of the Whole Model Rocket

Once all of the doable tests were performed, it was time to test the actual finished product.. The engineer uploaded code into the Arduino and the Inertial Measurement Unit (IMU), hooked them up to a 5v battery pack, and then sealed it into the actual rocket. The rocket was ready to be launched. The engineer then assembled the rocket launch system, and placed it on flat ground with no obstructions within a 100 feet. Then, they slid the rod of the launch system into the launch lugs of the rocket. They then physically connected their launch controller to the rocket using wires. When the apparatus was done, the rocket’s structure and layout looked like Figure 3. Figure 4 shows the rocket after being mounted onto the launch system.

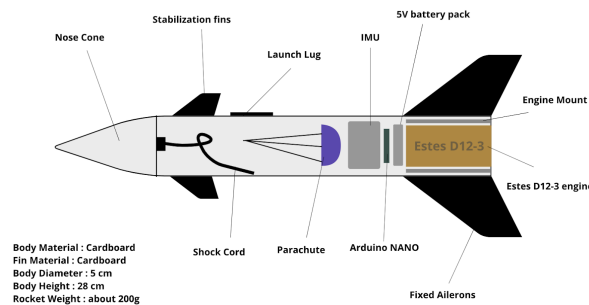


Fig 3: Detailed schematic of Model Rocket

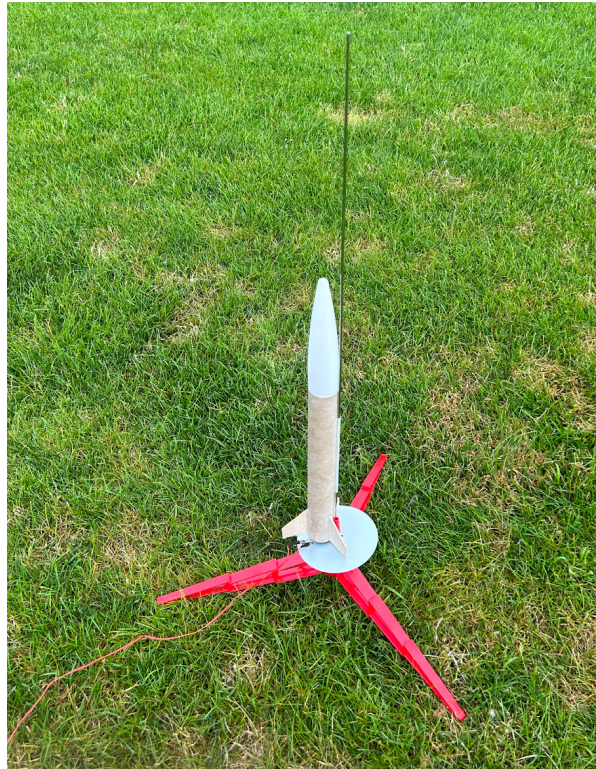


Fig 4: Rocket on Launch Apparatus

After inserting the safety key, the engineer pressed the launch button, which fired the engine, and the rocket started to accelerate very quickly off the ground. A spark of fire was visible at the bottom of the rocket as it ascended, but it quickly went out of view as it was cloudy on the day of launch.

## Results

Approximately eight seconds after launch, the rocket crash landed with speed. This meant that the parachute put into the rocket did not deploy, as the rocket would have descended a lot slower, and the engineer would have been able to see the parachute. The engineer approached the rocket when it seemed safe in order to retrieve the parts that were needed to verify the results. They noticed that the nose cone only came out halfway, which meant that there was no opening at the top for the parachute to deploy on the way down. This may have been caused by fitting the nose too tightly into the rocket. Luckily, though, the computers and the battery pack survived the flight test and the data was recorded. The altitude graph of the rocket is shown below in Figure 5.

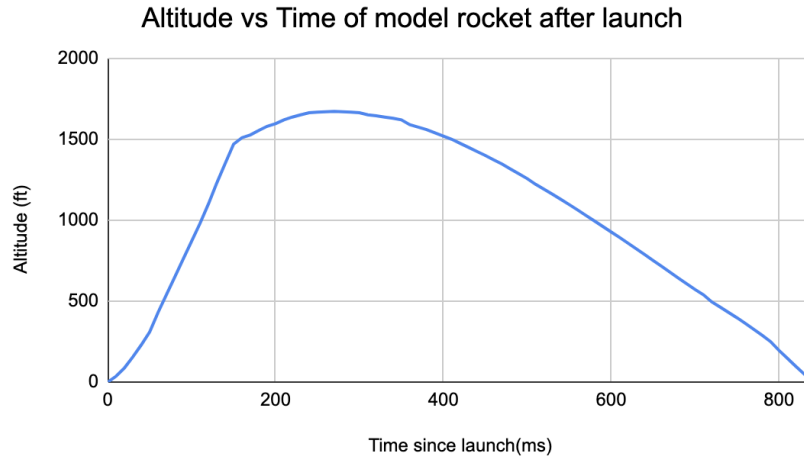


Fig 5: Altitude vs Time graph of Model Rocket after Launch

In this graph, it is visible that the thrust which caused the rocket to accelerate upwards lasted for about 160 milliseconds. This is indicated by the sharp change in the graph's trend. The rocket then rapidly slowed down once the thrust was over and reached the apogee of 1,600 feet at about 290 milliseconds after launch. This slowing down occurred due to gravity pulling the rocket down toward earth. Then, the rocket accelerated downward and hit the ground at about 840 milliseconds. The IMU also recorded the acceleration of the rocket in the Y direction, which is shown below in Figure 6.

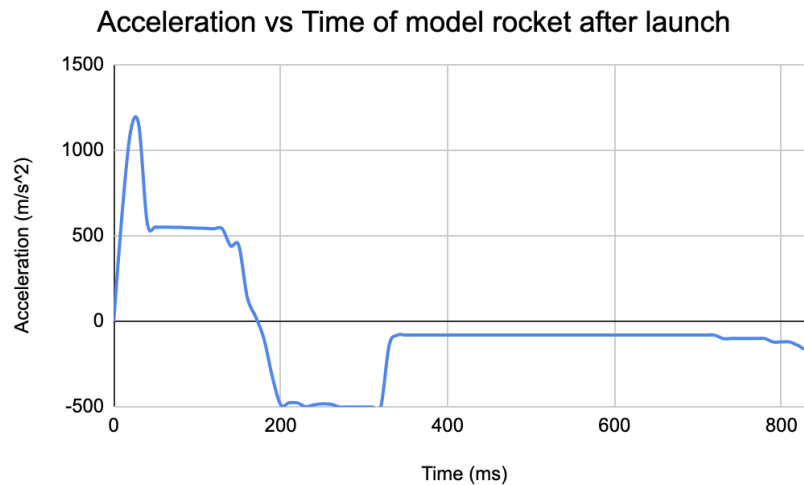


Fig 6: Vertical Acceleration vs Time of Rocket after Launch

Using the acceleration graph, the engineer calculated the velocity of the rocket at each of the data points and created a velocity vs time graph, shown below in Figure 7.

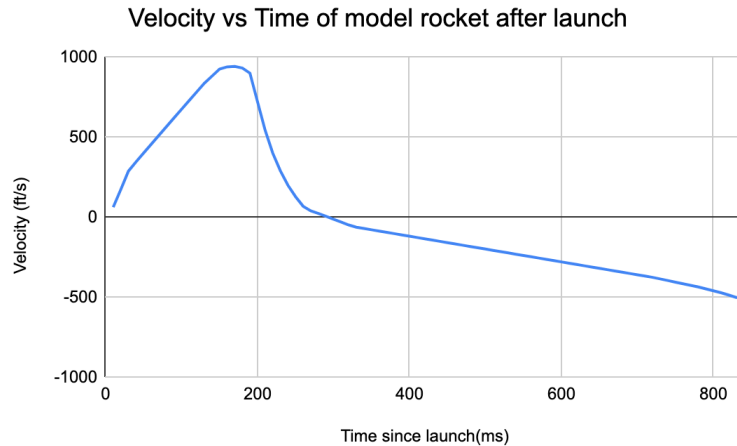


Fig 7: Velocity vs Time Graph of the Rocket after Launch

According to this graph, the fastest the rocket went was about 900 feet per second before steeply going back down to zero. On the way down, the fastest it reached was about 500 feet per second. When converted to miles per hour, this rocket easily fulfilled the speed requirement of 100 miles per hour.

### Conclusion

In conclusion, this rocket launch was a success, meeting most of the requirements that were assigned. A list of all requirements and results can be viewed in appendix A. It taught the new engineer how to go about the engineering design process and how to use it to create a model rocket from no prior experience. This project taught a new engineer all of the steps that an engineering system must go through before being completed. If the engineer had to do this again, they would change a lot of things, such as making a more detailed design and thinking more through before launch, and making reasonable requirements that could be fully tested.

### Works Cited

- Adams, C. (n.d.). What are the four fundamental methods of requirement verification? [Online forum post]. Modern Analyst. <https://www.modernanalyst.com/Careers/InterviewQuestions/tabid/128/ID/1168/What-are-the-four-fundamental-methods-of-requirement-verification.aspx>
- Halligan, R. (2022, October 4). *What is the significance of different types of requirements such as states and modes, functional, performance, external interface, environmental, resource, physical, other qualities and design?* Project Performance International. Retrieved October 4, 2023, from <https://www.ppi-int.com/resources/systems-engineering-faq/what-is-the-significance-of-different-types-of-requirements-such-as-states-and-modes-functional-performance-external-interface-environmental-resource-physical-other-qualities-and-design/>
- Systems engineering, trade study. (n.d.). AcqNotes. Retrieved October 4, 2023, from [https://acqnotes.com/acqnote/careerfields/trade-study#google\\_vignette](https://acqnotes.com/acqnote/careerfields/trade-study#google_vignette)
- What is the engineering design process?* (n.d.). TWI-global. Retrieved October 4, 2023, from <https://www.twi-global.com/technical-knowledge/faqs/engineering-design-process>

# **A Comprehensive Analysis on the State of Mirror Neurons for Research By Vincent Zhang**

## **Research Question**

Given their initial popularity and progressive downfall in the neuroscience research field, what is the current state of our understanding of mirror neurons as a research topic and what future research is needed to better understand the role of mirror neurons in animal and human learning and behavior?

## **Abstract**

Since their identification in the 1990s, mirror neurons have been lauded as a groundbreaking discovery in our understanding of human learning and behavior, with neuroscientist Vilayanur Ramachandran comparing its significance to the discovery of DNA. However, enthusiasm for mirror neurons has dissipated from its former glory, with mirror neurons recently dubbed the “most hyped concept in neuroscience”. This progressive drop in popularity has caused many to question mirror neurons' current role in our understanding of learning behaviors. The present paper will aim to examine three key concepts: the cause of the drop in popularity of mirror neuron research, current and past research disputing claims and identifying limitations of the concept of mirror neuron's role in explaining certain behaviors, and the direction of future research to further identify the role of mirror neurons.

## **Introduction**

Mirror neurons are classified as a type of neuron that triggers both motor and emotional responses as a result of observing someone else's actions. For example, an individual that happens to observe someone else yawning may also feel the urge to yawn as well, thus triggering the emotional responses correlated with yawning (e.g. tired and lethargic) and feeding into the idea that yawning is “contagious”. The discovery of this type of neuron can be credited to three Italian researchers: G. di Pellegrino, Vittorio Gallese, and Giacomo Rizzolatti (Di Pellegrino et al.). These researchers pioneered mirror neurons as a research topic through the macaque monkey. Essentially, the researchers found that when the macaque monkey observed another primate grabbing an object, a specific neuron fired within the macaque monkey's brain, preceding the behavioral action of the macaque grabbing the object as well. Despite the accidental nature of the discovery, the impact within the neuroscience community was substantial.

Although mirror neurons once consumed the neuroscience field, peaking in popularity in the mid 2010s, study on this subject saw a significant decline in popularity in recent years. This research paper intends to explain this decline as well as the current state of five different subtopics most associated with mirror neurons: action understanding, speech perception, empathy, imitation, and autism..

## Action Understanding

Action understanding has taken on many different definitions as a result of the numerous discoveries that have been made surrounding this topic. For example, Hickok defines action understanding as the concept that observation of “inherent semantics” within others can lead to the copying of these semantics by the subject (Hickok). However, many would agree that action understanding involves recognizing emotional states and intentions of others. Many researchers posited that mirror neurons were responsible for action understanding behaviors by converting observed actions into motor stimulation. This idea, however, has been drawn into question by recent research, with many claiming that the role of mirror neurons in action understanding might not be as influential as originally thought (Hickok; Heyes; Catmur; Cook et al.; Caramazza et al.). Moreover, like the multiple functions for mirror neurons, action understanding has been discovered to have a deeper level as well. For example, Hickok claims that action understanding isn’t simulating motor actions based on observations, but rather by understanding and executing the “goals” of the actions based on inferences made about the intentions of the individuals performing the action. Therefore, action understanding cannot be explained by the action of mirror neurons alone, prompting future research regarding the new understanding of action understanding (Hickok). Based on this evidence, the conclusion can be reached that mirror neurons do not play a major role in action understanding.

So what, if any, role do mirror neurons play in action understanding? While the theory of mirror neurons being the basis for action understanding is quite unpopular in recent times, many papers do not deny that mirror neurons have a minor role in action understanding. For example, studies show that individuals with damage to the area of the brain thought to include mirror neurons not only find it difficult to produce an action, but also to recognize the sound of the action—differentiating action *production* from action *recognition* and indicating that a minor role is possible within mirror neurons (Mahon). In addition, neurophysiological and brain imaging evidence indicates that sensory representation of an observed action can be translated into motor representation, and future research is needed that focuses on the reasons and not just the goals of the action (Sinigaglia). As a result, the conclusion can be made that while mirror neurons are not the only kind of neuron involved in action understanding, they are likely involved to some degree.

With all this in mind, what should future research surrounding mirror neurons in action understanding aim to do? Since mirror neurons have been found to play a role within action understanding, it is essential that researchers identify the specific function of mirror neurons as well as emphasize that the role is likely lower-level processes like recognizing observed actions and not higher-level processes like intention understanding.

## Speech Perception

With the initial discovery of mirror neurons in the 1990s, researchers discovered that there was a significant link between activity in mirror neurons and the Broca’s area (BA) of the frontal cortex, which is involved in speech production. As a result, they made the conclusion that



there was a strong relationship between mirror neurons and speech, and hypothesized that mirror neurons played a causal role in speech perception (Rizzolatti et al.; Gallese et al.). However, findings from recent research suggest that the relationship might not be as strong as originally thought.

Researchers tested this theory by testing whether individuals with lesions in the motor area and mirror system would encounter trouble when perceiving speech. They gathered participants with Broca's aphasia (a disorder that impairs speech production) who had lesions in the mirror neuron system assessed their word comprehension and speech discrimination. In the former test, participants were asked to indicate the correct picture that matched a word. In the latter test, participants heard pairs of syllables and were questioned about if two items presented were identical (Rogalsky et al.). The results of the experiment showed that participants with lesions in the mirror system exhibited high levels of performance of speech perception through all the tests, disproving the original theory of the critical link between mirror neurons and speech perception.

Prior to the discovery of mirror neurons, the Motor Theory of speech perception was proposed, which claimed that human perception of speech involves the motor system recognizing phonetic gestures rather than sounds (Lieberman et al.). This theory received mixed support, and other theories emerged that do not include the involvement of the motor system in the recognition of phonetic features of speech. This all changed with the discovery of mirror neurons which provided evidence for the theory that the motor areas of the brain are primarily responsible for speech perception and ultimately launched the motor theory back into popularity. While it has been said that the mirror neurons are the "neural basis" of speech perception, some researchers claim that the motor theory provides a more detailed view on the complex relationship between speech production and speech perception (Lotto et al.). Although there is some evidence for this theory, including the finding that motor areas of the brain are active during speech perception, the motor theory also shares the view that damage in Broca's area will produce deficits in speech perception. However, previous research has shown that the ability to recognize speech is unaffected within individuals with lesions in the motor areas related to speech.

In summary, while some researchers can confidently say that a relationship between speech perception and mirror neurons does exist, it is still unknown whether mirror neurons' role is limited to speech production or includes speech perception and/or the phonetic matching process. Consequently, future research concerning mirror neurons should strive to lean away from speech perception and more towards identifying the primary function of mirror neurons. In addition, future research concerning speech perception should focus on developing a new theory that includes the role of motor areas of the brain in speech.

## **Empathy**

Empathy, one of the most significant cognitive responses within a living organism, has been described as the ability to understand the internal states of others. Considered a survival

skill, empathy has been known to contain both low and high level cognitive processes. For example, primates use facial expressions to communicate both emotions and intentions throughout their lifespan, ultimately allowing them to accurately interpret and mimic these expressions (Mancini et al.). The mimicking aspect that the primates exhibit would be considered a low level process, whereas the interpreting aspect would be considered a high level process. So how does empathy relate to mirror neurons? Empathy has been relatively understudied in relation with mirror neurons. While empathy and mirror neurons are major topics in research on their own, the relationship between them has not been studied to a large extent, and most of the evidence of their link is speculative. As a result, a case can be made for both the support of empathy with mirror neurons as well as the denial of any correlation between the two.

On one hand, it would be obvious to link the mimicry involved in empathetic behaviors with the imitation role of mirror neurons. However research has not provided conclusive evidence for this link (“The Psychology of Emotional and Cognitive Empathy”). While the motor resonance behaviors involved in empathy are important, they do not explain the empathetic responses that humans appear to think and act out. Activity in the motor areas thought to contain mirror neurons does take place when humans view certain behaviors that are associated with empathetic responses (e.g., touching a hot stove or smiling expressions); however, other higher level neural processes also take place. These higher level activities are thought to inform the motor responses, rather than the motor activity informing the emotional response (i.e., it is believed to be a top down and not a bottom up process).

In contrast, some researchers believe that mirror neurons play a central role in empathy. For example, Ferrari and Coudé claim that the mirroring of emotions within humans and some animals are responsible for triggering basic forms of empathy by activating “emotional brain centers” thus evoking corresponding feelings (Ferrari, & Coudé). Since empathy is quite difficult to conduct research on due to the vagueness of the concept itself and the ethical concerns of performing recordings of specific activity of neurons in humans that requires invasive procedures, even less research has been conducted about the relationship between empathy (a psychology focused topic) and mirror neurons (a neuroscience focused topic). As a result, many people have just assumed there to be a link between the two despite the lack of causation. If researchers were to look into this topic further, then there is a possibility that a clear link could be established, but creativity is needed to develop experiments that can prove the centrality of mirror neurons' role in empathy behaviors. However, as of right now, a solid conclusion cannot be made and additional information needs to be obtained before a conclusive statement can be made about the correlation between mirror neurons and empathy.

### **Imitation**

Out of all the behaviors associated with mirror neurons, imitation is arguably the most favored within research. In fact, the basic premise of mirror neurons revolve around the actions of observing and performing a motor action based on an individual stimulus. 30 years prior, imitation was viewed as a behavior that most life forms could exhibit. Yet as more research has

been conducted, a greater appreciation has been seen for imitation among organisms, with a general consensus stating that there are two distinct levels of imitation: physical and psychological (Dijksterhuis). Physical, which has been exhibited by many life forms before, involves imitating motor actions such as facial and manual gestures (Meltzoff & Moore) in addition to speech style and habits (Eriksson et al.) through observation. However, higher intellectual life forms (humans, monkeys, etc) exhibit more complex forms of psychological imitation such as stereotype and trait activation; a new aspect of imitation that makes us the social animals we inherently are.

With all this in mind, a potential question is raised: how has research behind imitation within the mirror system evolved? In a study done by Catmur, Walsh, and Heyes, transcranial magnetic stimulation was used to measure motor-observed potential size of the abduction movements of the index and little finger. The experiment tested to see the effect of countermirror training on the mirror system by asking participants to conduct little finger movements while being shown index finger movements and to conduct index finger movements while being shown little finger movements. Through this study, researchers were able to discover that natural mirror system responses weren't obsolete and that temporary modification was possible when provided with countermirror training, ultimately opening a new perspective to imitation behind mirror neurons (Catmur et al.). Furthermore, Halsband, Schmitt, Weyers, Binkofski, Grützner, and Freund conducted a study that aimed to discover whether apraxia, or reduced fine motor ability as a result of lesions in the brain, is correlated with the execution of motor acts. The study gathered patients with lesions in the left parietal lobe, right parietal lobe, right premotor area, and no lesions at all (control), subsequently showing them different videos of certain gestures and asking the patients to imitate the gesture shown (Halsband et al.). The study found that patients with lesions in the left parietal lobe had a more difficult time when it came to imitation in comparison to patients with lesions in the right parietal lobe and the right premotor area. In addition, gestures involving an external stimulus were found to be easier for the patients with lesions in the left parietal lobe yet no clear correlation was established between comprehending the gestures and executing them. Through this study, researchers were able to deduce that the left parietal lobe was the most affected when it came to imitation behaviors and that apraxia didn't affect comprehension as much as it did execution. Lastly, brain activity involving imitation has been speculated to be within the Broca's area for quite a long time, with researchers Iacoboni, Woods, Brass, Bekkering, Mazziotta, and Rizzolatti coming to this conclusion back in 1999 (Iacoboni et al.). However in recent years, Activation Likelihood Estimation (ALE) meta-analysis revealed in a study done by Caspers, Zilles, Laird, and Eickhoff that there was a distinction between observation and imitation networks when it came to involvement in Broca's area. While both networks were present in BA 44, observation was found to be most prevalent amongst more rostro-dorsal locations such as BA 45 while imitation was found to be most prevalent amongst more ventro-dorsal locations such as BA 44. In combination with the previous study, many researchers were able to come to the conclusion that the observation aspect of

imitation was completely independent from the act of imitation, thus furthering even more research in the future.

Based on both cross sectional and causal evidence shown in these studies, not only were we able to deduce that a clear difference between observation and imitation existed, but also that there is strong evidence for the mirror system's (system of mirror neurons) role in imitation behaviors. However, there are still many more topics that need to be researched such as whether imitation behaviors are also present in other brain areas besides Broca's area, thus leaving researchers with much more to consider when it comes to imitation with mirror neurons.

## **Autism**

Unlike imitation, the relationship between autism spectrum disorder (ASD) and mirror neurons has come under a lot of scrutiny. In order to discuss autism, however, the "broken-mirror" theory must be addressed. The "broken-mirror" theory asserts that the basis of ASD is a lack of imitative behavior as a result of dysfunction in the frontal and parietal brain regions (areas associated with mirror neurons). As a result, many researchers made the association that ASD was correlated with dysfunction in mirror neurons, with many stating that autism in relation to mirror neurons is a promising direction for research (Williams). However in more recent years, evidence that contradicts the "broken-mirror" theory has emerged.

One of the studies that casted doubt on the "broken-mirror" theory is a study done by Sowden, Koehne, Catmur, Dziobek, and Bird. Prior to the study, supporters of the "broken-mirror theory" would claim that people with ASD would perform worse on automatic imitation tests than individuals without ASD. To test this, the study gathered 60 adults with ASD and 60 adults without ASD to perform either a middle or index finger raise while being shown either the same or opposite motion. (Sowden et al.). From this, they were able to conclude that when shown an observation of the same action both groups tended to exhibit a stronger imitation effect compared to when they were shown the opposite motion, providing evidence against the "broken-mirror" theory.

Other studies have since been done that found no difference in imitation behaviors in individuals with ASD, further casting doubt on the "broken-mirror" theory and no correlation has been found with people of autism and dysfunction in the areas of the brain thought to contain mirror neurons. Furthermore, most recent studies have rejected the concept that autism may provide an inherent disadvantage in imitation behaviors and some promising new models of ASD have been proposed replacing the old theory (Fan et al.; Khalil et al.; Heyes & Catmur). In conclusion, research regarding autism and mirror neurons may still be pursued, however there is no concrete evidence to support a relationship between autism and mirror neuron dysfunction.

## **Conclusion**

Now equipped with knowledge about all five functions, what can we conclusively say about mirror neurons as a research topic? From what we gathered about the different functions, the conclusion can be made that mirror neurons likely do not have a major influence on many of

the functions as they were once thought to have had. Evidence from research supporting this limited role have led to the decrease in popularity of mirror neurons research in recent years. Despite this, I believe that a clear understanding of their main function has not been discovered yet. While some areas like speech perception are not as promising, others such as empathy may be better understood with more research as mentioned before. Beyond these functions, more may exist that have yet to be uncovered. Consequently, researchers should adjust their perspectives and focus on new or promising paths that may help us identify the main reason behind the existence of mirror neurons.

## Works Cited

- Caramazza, Alfonso, et al. "Embodied cognition and mirror neurons: a critical assessment." *Annual review of neuroscience* 37 (2014): 1-15.
- Caspers, Svenja, et al. "ALE meta-analysis of action observation and imitation in the human brain." *Neuroimage* 50.3 (2010): 1148-1167.
- Catmur, Caroline, Vincent Walsh, and Cecilia Heyes. "Associative sequence learning: the role of experience in the development of imitation and the mirror system." *Philosophical Transactions of the Royal Society B: Biological Sciences* 364.1528 (2009): 2369-2380.
- Catmur, Caroline. "Unconvincing support for role of mirror neurons in "action understanding": commentary on Michael et al.(2014)." *Frontiers in Human Neuroscience* 8 (2014): 553.
- Cook, Richard, et al. "Mirror neurons: from origin to function." *Behavioral and brain sciences* 37.2 (2014): 177-192.
- Dijksterhuis, Ap. "Why we are social animals: The high road to imitation as social glue." *Perspectives on imitation: From neuroscience to social science* 2 (2005): 207-220.
- Di Pellegrino, Giuseppe, et al. "Understanding motor events: a neurophysiological study." *Experimental brain research* 91 (1992): 176-180.
- Eriksson, Anders, Carmen Llamas, and Dominic Watt. "The disguised voice: imitating accents or speech styles and impersonating individuals." *Language and identities* 8 (2010): 86-96.
- Fan, Yang-Teng, et al. "Unbroken mirror neurons in autism spectrum disorders." *Journal of Child Psychology and Psychiatry* 51.9 (2010): 981-988.
- Ferrari, Pier F., and Gino Coudé. "Mirror neurons, embodied emotions, and empathy." *Neuronal correlates of empathy*. Academic Press, 2018. 67-77.
- Gallese, Vittorio, et al. "Action recognition in the premotor cortex." *Brain* 119.2 (1996): 593-609.
- Halsband, U., et al. "Recognition and imitation of pantomimed motor acts after unilateral parietal and premotor lesions: a perspective on apraxia." *Neuropsychologia* 39.2 (2001): 200-216.
- Heyes, Cecilia, and Caroline Catmur. "What happened to mirror neurons?." *Perspectives on Psychological Science* 17.1 (2022): 153-168.
- Heyes, Cecilia. "Where do mirror neurons come from?." *Neuroscience & Biobehavioral Reviews* 34.4 (2010): 575-583.
- Hickok, Gregory. "Do mirror neurons subserve action understanding?." *Neuroscience letters* 540 (2013): 56-58.
- Hickok, Gregory. "Eight problems for the mirror neuron theory of action understanding in monkeys and humans." *Journal of cognitive neuroscience* 21.7 (2009): 1229-1243.
- Iacoboni, Marco, et al. "Cortical mechanisms of human imitation." *science* 286.5449 (1999): 2526-2528.
- Kaplan, Jonas T., and Marco Iacoboni. "Getting a grip on other minds: Mirror neurons, intention understanding, and cognitive empathy." *Social neuroscience* 1.3-4 (2006): 175-183.

- Khalil, Radwa, et al. "Social decision making in autism: On the impact of mirror neurons, motor control, and imitative behaviors." *CNS neuroscience & therapeutics* 24.8 (2018): 669-676.
- Liberman, Alvin M., et al. "Perception of the speech code." *Psychological review* 74.6 (1967): 431.
- Lotto, Andrew J., Gregory S. Hickok, and Lori L. Holt. "Reflections on mirror neurons and speech perception." *Trends in cognitive sciences* 13.3 (2009): 110-114.
- Mahon, Bradford Z. "Action recognition: is it a motor process?." *Current Biology* 18.22 (2008): R1068-R1069.
- Mancini, Giada, Pier Francesco Ferrari, and Elisabetta Palagi. "In play we trust. Rapid facial mimicry predicts the duration of playful interactions in geladas." *PloS one* 8.6 (2013): e66481.
- Meltzoff, Andrew N., and M. Keith Moore. "Imitation of facial and manual gestures by human neonates." *Science* 198.4312 (1977): 75-78.
- Rizzolatti, Giacomo, et al. "Premotor cortex and the recognition of motor actions." *Cognitive brain research* 3.2 (1996): 131-141.
- Rogalsky, Corianne, et al. "Are mirror neurons the basis of speech perception? Evidence from five cases with damage to the purported human mirror system." *Neurocase* 17.2 (2011): 178-187.
- Sinigaglia, Corrado. "What type of action understanding is subserved by mirror neurons?." *Neuroscience letters* 540 (2013): 59-61.
- Sowden, Sophie, et al. "Intact automatic imitation and typical spatial compatibility in autism spectrum disorder: Challenging the broken mirror theory." *Autism Research* 9.2 (2016): 292-300.
- "The Psychology of Emotional and Cognitive Empathy." *The Psychology of Emotional and Cognitive Empathy* | Lesley University, [lesley.edu/article/the-psychology-of-emotional-and-cognitive-empathy](http://lesley.edu/article/the-psychology-of-emotional-and-cognitive-empathy).
- Williams, Justin HG. "Self-other relations in social development and autism: multiple roles for mirror neurons and other brain bases." *Autism Research* 1.2 (2008): 73-90.

## How has Dark Matter Influenced Structure Formation in our Universe? By Conor Naughton

This paper discusses dark matter in detail, such as theorizing its composition and describing ways in which we know it exists. The paper illustrates how dark matter can create structures in our universe. Topics include dark matter, the standard model of particle physics, and structure formation.

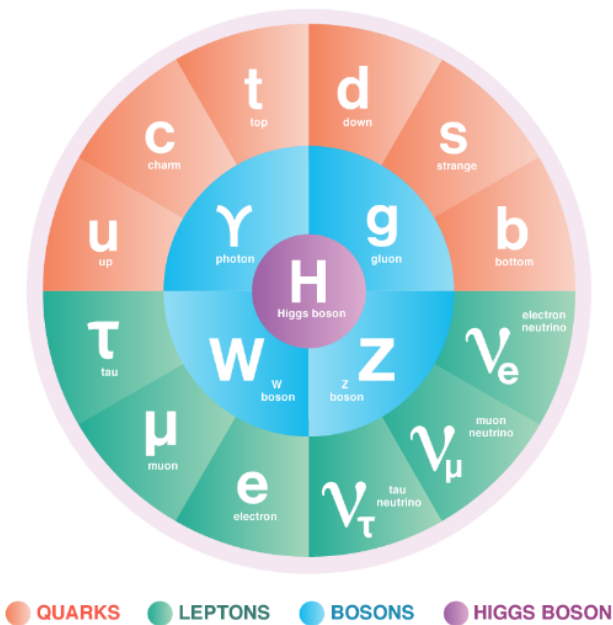
Imagine everything here on Earth. Every plant, animal, person, and building. Now add every other planet and its contents, every star, and every gas. This is only 5% of all the matter in our universe. Dark energy only accounts for about 68% of the rest. So what makes up the remainder? Dark matter is a theorized form of matter that takes up roughly 27% of all the matter in our universe ((*Dark Matter and the Early Universe: A Review*, 2021)). Dark matter is called dark as it does not interact with the electromagnetic force, meaning it does not emit electromagnetic radiation, making it incredibly difficult to detect and measure. Some gravitational effects that can be measured cannot be explained without assuming more matter is present. This is where the theory of dark matter comes into play. Although incredibly difficult with today's methods, there are still a few different ways that we can detect the presence of dark matter. One of these processes is called gravitational lensing. Gravitational lensing is the way that light bends when traveling through massive objects ((*What Is Dark Matter?*, 2012)). For instance, if you were looking at coins at the bottom of a pool, those coins are going to appear deformed. This is because the object in the middle (in this case water) has mass. This is applicable when looking at very far away objects, such as a quasar, and something gets in the way, such as a galaxy cluster. By looking at the deformation of background galaxies, we can detect the mean distribution of dark matter in our universe ((*What Is Dark Matter?*, 2012)). Another way of detecting dark matter is called galaxy rotation curves. In a spiral galaxy, such as the Milky Way, the arms rotate around the center, which is where a majority of the light comes from. However, this is not where all the mass comes from. If all the luminous mass was all the matter, then a spiral galaxy could be classified as a point mass, similar to our solar system ((*Wikipedia*, 11 Jan. 2021, [en.wikipedia.org/wiki/Galaxy\\_rotation\\_curve](https://en.wikipedia.org/wiki/Galaxy_rotation_curve))). A point mass is defined as a system where all the mass of an object is at a single point. Due to Johannes Kepler's 2nd Law of Gravitation, it is expected that the velocities of a rotating body would decrease the further you are from the center during rotation. However, this is not the case. Instead, the galaxy rotation curve remains constant throughout the entirety of the galaxy's range ((Karill Zatrimarylov)). If Kepler's laws of





gravitation are assumed to be correct, then the mass distribution must not be similar to that of our solar system, and therefore not a point mass ((*Wikipedia*, 11 Jan. 2021, en.wikipedia.org/wiki/Galaxy\_rotation\_curve.)). Since the luminous mass measured does not match the total mass needed to rotate in the way that it does, there must be something else in the galaxy ((*What Is Dark Matter?*, 2012)). This solidifies the involvement of dark matter. However the question still remains: How has dark matter influenced structure formation in our universe?

The standard model of particle physics is currently the best way at explaining the most basic building blocks in our universe. It explains how all known matter is created by quarks and leptons, which are subatomic particles ((Reissalman & Murayama, n.d.)). Furthermore, it explains how the force carrying particles, bosons, interact with the quarks and leptons



((Reissalman & Murayama, n.d.)). On top of this, the standard model of particle physics illustrates 3 out of the 4 fundamental forces of the universe ((*Standard Model*, n.d.)). Photons, which have both energy and light, are the carriers for the electromagnetic force ((W, n.d.)). The strong force is carried by the gluon, and the weak force is carried by the W and Z bosons ((*The The Standard Model of Particle Physics - DOE Standard Model*, n.d.)). However, the standard model is incomplete. It does not explain the 4th fundamental force, gravity. Even though the effect of gravity is so small as to be considered negligible at the scale of particles, we still need to understand it. It is

theorized to be carried by the graviton, a separate type of boson, but we have no proof that it actually exists ((CERN)). The Higgs Boson, a separate type of particle, gives mass to quarks, charged leptons, such as electrons, and the W and Z bosons. However, we do not know whether or not the Higgs Boson gives mass to neutrinos, which are ghostly leptons that rarely interact with other matter ((Reissalman & Murayama, n.d.)). Another way that the standard model has been proven incomplete is when it relates to dark matter. As previously stated, the standard model of particle physics uses quarks and leptons to explain all known matter, but we do not know what dark matter is made of. The standard model is missing more particles which could, in theory, explain dark matter and dark energy.

The universe, which was created by the Big Bang nearly 13.8 billion years ago, began in a hot, dense, and almost completely homogenous state ((Joel Primack)). After roughly 50,000 years, the density of radiation and matter equalized, letting particles begin to form ((*Dark Matter*, n.d.)). Later, the primordial hydrogen and helium were ionized into nuclei and free

roaming electrons. Finally, after about 400,000 years after the big bang, the universe cooled down enough to let protons and neutrons form, creating hydrogen atoms. Eventually the smaller gravitationally bound structures, such as Structure formation in the very early universe - Physics matter peaks, containing the first stars and stellar clusters formed, and these subsequently merged with dark matter and gas to form galaxies, galaxy groups, galaxy clusters, and superclusters ((*Structure Formation*, n.d.)). Since dark matter is not affected by radiation, it was crucial to the early development of The dark matter in the early universe collapsed, forming dark matter halos before regular, baryonic matter could, rapidly accelerating the formation of structures in the universe ((*Structure Formation*, n.d.)). At this stage, the radiation and pressure forces which do not interact with dark matter were too much for the luminous, baryonic matter ((*Structure Formation*, n.d.)). In fact, matter would not have been able to form if it were just baryonic matter in our universe. Using deductive reasoning, scientists have figured out that there must be something else, ie; dark matter, that allows for celestial structures, such as galaxies, planets, and stars, to form.

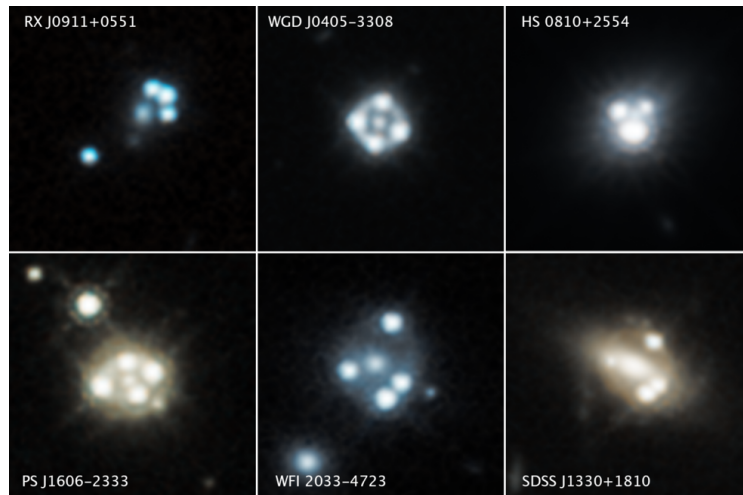
Although we know of some sort of substance where matter cannot exist, we do not actually know what dark matter is. What we know is that dark matter and dark energy account for roughly 95% of all of the total

mass-energy content of the universe. We know that dark matter is not made of any particles that fall into the standard model of particle physics ((Cook, n.d.)). We know that dark matter cannot be failed stars, gas clouds, dust grains, asteroids or comets, basketball-sized clumps of normal matter, ionized plasma, or black holes ((Ethan, 2020)).

Furthermore, the standard

Gravitational lensing of quasars from dark matter model -

is also incomplete. There are a few NASA, ESA, A. Nierenberg (JPL) and T. Treu (UCLA) ideas that go unexplained by it, for example, there is no particle that explains the force of gravity, while the other 3 forces can be given with particles that fit into the standard model. Also dark matter could not be explained with anything in the standard model. However, recently, we proved that dark matter is “cold,” meaning it does not have a high velocity ((Andreoli et al., 2022)). This changed our entire perception of dark matter. Using their Hubble Space Telescope, NASA found the smallest known dark matter clumps using gravitational lensing, which could not be formed if the dark matter particles were “warm,” or traveling at a high velocity ((Andreoli et al., 2022)). The relative amount of small structures inside the dark matter clumps provide



some clues as to the nature of dark matter. "The particle properties of dark matter affect how many clumps form. That means you can learn about the particle physics of dark matter by counting the number of small clumps," says Anna Nierenberg at the Jet Propulsion Laboratory in Pasadena, California ((Andreoli et al., 2022)). The information theorized in the study could help complete the currently-imperfect standard model of particle physics by adding a particle that explains both dark matter and the force of gravity. In fact, scientists at Fermilab are working on The Axion Dark Matter Experiment (ADMX), where they are trying to discover a hypothetical particle called an axion, which is the theorized particle on the standard model that explains dark matter ((Science | Particle Physics | *Dark Matter and Dark Energy*, 2020)). The eventual discovery of the axion would be extremely beneficial to the scientific community. With the discovery of the axion, scientists could figure out what dark matter consists of, and, eventually, figure out ways to directly view it. This would also complete the standard model, helping to discover the boson that is responsible for carrying the gravitational force. Since we can predict the mass of the axion ((roughly 1 100 trillionth the mass of an electron)), we can determine that it would, in fact, be a main component of dark matter ((Hooft, n.d.)).

Structure formation in our universe is one of many reasons that life was able to form. Without it, no galaxies, gasses, stars, or even planets could form, making life as we know it impossible. Dark matter is a crucial part of structure formation, and therefore, the creation of life. Dark matter was the cause of the formation of galaxies, galaxy clusters, and superclusters which fill our universe to this day. Since we do not technically know what dark matter is made up of, we can't truly define it. However, we know what it does. With scientists working on discovering the particles that create dark matter, particle physics is on the brink of a huge discovery that could change our understanding of the universe. Once we can fully complete and understand the standard model of particle physics, we can explain matter, energy, and forces, which make up most of our universe.

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## Works Cited

- (2022, October 2). . - YouTube. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Galaxy\\_rotation\\_curve](http://en.wikipedia.org/wiki/Galaxy_rotation_curve).
- Andreoli, C., Weaver, D., Treu, T., Gilman, D., & Villard, R. (2022, October 2). . . - YouTube. Retrieved September 10, 2023, from <http://www.nasa.gov/feature/goddard/2020/hubble-detects-smallest-known-dark-matter-clumps/>.
- Cook, M. (n.d.). *DOE Explains...Dark Matter*. Department of Energy. Retrieved September 10, 2023, from <http://www.energy.gov/science/doe-explainsdark-matter>
- Dark matter*. (n.d.). Wikipedia. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Dark\\_matter](http://en.wikipedia.org/wiki/Dark_matter)
- Dark matter and the early Universe: A review*. (2021, April 8). Science Direct. <https://doi.org/10.1016/j.pnpnp.2021.103865>
- Ethan, S. (2020, March 13). *5 Things We Know About Dark Matter (And 5 We Don't)*. Forbes. Retrieved September 10, 2023, from <http://www.forbes.com/sites/startswithabang/2020/03/13/5-thing-we-know-about-dark-matter-and-5-we-dont/?sh=4bfc81e836f8>
- Hooft, G. T. (n.d.). *Axion*. Wikipedia. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Axion#Pre-inflationary\\_scenario](http://en.wikipedia.org/wiki/Axion#Pre-inflationary_scenario)
- Musoke, N., Hotchkiss, S., & Easter, R. (2022, October 2). *Structure Formation in the Very Early Universe*. Physics Viewpoint. Retrieved September 10, 2023, from <https://doi.org/10.1103/physrevlett.124.061301>
- Photon energy*. (n.d.). Wikipedia. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Photon\\_energy](http://en.wikipedia.org/wiki/Photon_energy)
- Primack, J. (2022, October 2). . . - YouTube. Retrieved September 10, 2023, from <http://arxiv.org/pdf/astro-ph/9707285.pdf>
- Riesselmann, K., & Murayama, H. (n.d.). *DOE Explains...the Standard Model of Particle Physics*. Department of Energy. Retrieved September 10, 2023, from <http://www.energy.gov/science/doe-explainsthe-standard-model-particle-physics>
- Rizzo, T. G. (2022, October 2). . . - YouTube. Retrieved September 10, 2023, from [https://doi.org/10.1007/jhep11\(\(2021\)\)035](https://doi.org/10.1007/jhep11((2021))035)
- Science | Particle Physics | Dark matter and dark energy*. (2020, April 27). Fermilab. Retrieved September 10, 2023, from <http://www.fnal.gov/pub/science/particle-physics/experiments/dark-matter-and-dark-energy.html>
- Searching for dark matter*. (n.d.). Sanford Underground Research Facility. Retrieved September 10, 2023, from <http://sanfordlab.org/feature/searching-dark-matter>
- The Standard Model*. (n.d.). CERN. Retrieved September 10, 2023, from <http://home.cern/science/physics/standard-model>

*Standard Model*. (n.d.). Wikipedia. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Standard\\_Model#Construction\\_of\\_the\\_Standard\\_Model\\_Lagrangian](http://en.wikipedia.org/wiki/Standard_Model#Construction_of_the_Standard_Model_Lagrangian).

*Structure formation*. (n.d.). Wikipedia. Retrieved September 10, 2023, from [http://en.wikipedia.org/wiki/Structure\\_formation#Modelling\\_structure\\_formation](http://en.wikipedia.org/wiki/Structure_formation#Modelling_structure_formation)

Sutter, P. (2022, Mar 10). (...). (...) - Wiktionary. Retrieved September 10, 2023, from <http://www.livescience.com/what-are-photons>.

W, M. (n.d.). *Photons as Carriers of the Electromagnetic Force* | *Physics Van* | UIUC. Physics Van. Retrieved September 10, 2023, from <http://van.physics.illinois.edu/ask/listing/2348>

*What is Dark Matter?* (2012, February 22). NASA. Retrieved September 8, 2023, from <http://www.nasa.gov/audience/forstudents/9-12/features/what-is-dark-matter.html>.

## **Parenting Styles and the Development of Mood Disorders By Anushka Shinde**

### **Abstract**

Mood disorders are a prominent category of mental health concerns globally, holding the second highest prevalence of all psychiatric disorders (NIMH). Globally about 1 in every 3 women and 1 in every 5 men suffer from depression and other conditions such as bipolar disorder and schizophrenia (Dattani et al.). Approximately 21.4 percent of the United States's population suffers from at least one form of mood disorder, (National Institute of Mental Health [NIMH]). This research paper seeks to explore the correlation between parenting styles and the emergence of mood disorders during adolescence and early adulthood. It will review key symptoms described in the literature for Major Depressive Disorder and Bipolar Disorder, two significant mood disorders. It will then assess the prevalence and development of mood disorders in correlation to the different parenting styles, including permissive, authoritative, authoritarian, and neglectful.

### **Introduction**

Moods are long-lasting emotional states, while feelings are specific emotional experiences triggered by a certain event. Mood disorders are characterized by major changes in an individual's mood state, typically resulting in depression or mania. Depression is described as prolonged periods of sadness and loss of interest (American Psychiatric Association [APA]). According to the DSM-5-TR (APA), mania can be described as a distinct period of abnormally and persistently elevated, expansive, or irritable mood, which can also impact an individual's social and daily functioning. Hypomania consists of the above symptoms as well, but the symptoms persist for shorter periods and are less severe. Mood disorders have a concerningly high prevalence in the United States with 21.4 percent of the population being diagnosed with them (National Institute of Mental Health [NIMH]).

Mood disorders can be influenced by many factors including genetic predisposition and environmental factors (APA). Family dynamics, specifically parenting styles, are one of the numerous environmental factors associated with the development of mood disorders. According to Baumrind, there are three categories of parenting styles authoritative, authoritarian, and permissive. Later Maccoby added the category of neglectful parenting to Baumrind's original three. Authoritarian parenting is characterized by high levels of control and high expectations of the child (Baumrind). Authoritative parenting consists of a balance between warmth and control (Baumrind). Permissive parenting is portrayed as easy-going with low control and discipline, primarily focused on warmth and nurturing (Baumrind). Finally, neglectful parenting is characterized by low levels of warmth and control (Maccoby). This paper aims to explore three specific mood disorders (Bipolar I Disorder, Bipolar II Disorder, and Major Depressive Disorder) and the research on how exposure to specific parenting styles in childhood contributes to the development of these disorders.

## **Mood Disorders–Bipolar I disorder**

Bipolar I disorder is a mental health condition characterized by extreme mood swings that range from manic episodes to depressive episodes (APA). Individuals with bipolar I disorder experience periods of intense excitement, heightened energy, and impulsivity during manic episodes, which can lead to risky behaviors and impaired judgment. These manic episodes are often followed by periods of deep sadness, loss of interest, and a lack of energy during depressive episodes (APA). The transition between these mood states can be abrupt and disruptive, significantly impacting a person's daily functioning and overall quality of life (Mayo Clinic). Treatment for bipolar I disorder typically involves a combination of medication, therapy, and lifestyle adjustments to help manage and stabilize mood fluctuations (NIMH).

## **Bipolar II disorder**

Bipolar II is a mental health condition consisting of recurring episodes of depression and hypomania (APA). Unlike bipolar I disorder, individuals with bipolar II disorder do not experience full-blown manic episodes; rather, they go through periods of hypomania, which are milder and less disruptive than mania. During these episodes, they feel an increase in energy, creativity, and productivity. However, these episodes are often followed by depressive episodes marked by profound sadness, loss of interest, and a decreased ability to function. Bipolar II disorder can be challenging to diagnose, as the hypomanic episodes are less noticeable. With proper treatment and support, individuals with bipolar II disorder can achieve stability and lead fulfilling lives (McIntyre).

## **Major Depressive Disorder**

Major depressive disorder is a common and serious mental health condition characterized by persistent feelings of sadness, hopelessness, and a loss of interest or pleasure in activities (APA). The disorder goes beyond the normal fluctuations in mood that everyone experiences and can significantly impact a person's daily functioning and quality of life (APA). Symptoms of major depressive disorder may also include fatigue, changes in appetite and sleep patterns, difficulty concentrating, feelings of guilt or worthlessness, and even thoughts of death or suicide, which can last anywhere between six to twelve months (APA). The exact causes of major depressive disorder are not fully understood, but a combination of genetic, biological, environmental, and psychological factors may contribute to its development (APA). Treatment for major depressive disorder often involves a combination of medication, therapy, and behavioral interventions (APA). With appropriate treatment and support, individuals with major depressive disorder can experience relief from their symptoms and regain a sense of well-being and functionality (APA).

## **Relationship Between Parenting Styles and Child Mood Disorders**

Research results point to a relationship between parenting styles and the level of depression symptoms exhibited by children. According to a study by Ebrahimi et al, the

parenting styles of authoritative and permissive parenting were correlated with lower depression symptoms, while authoritarian and neglectful parenting was associated with higher depression symptoms. In addition, a study by Rostami, M., & Saadati, N. concluded that an authoritarian parenting style predicted mood disorders, specifically depression.

Researchers Sharma et al. conducted a study with 50 females and 50 males to examine the relationship between parenting styles and depression in adolescents. Authoritarian parenting was found to have a significant positive correlation with depression whereas permissive parenting had a significant negative correlation with depression (Sharma et al.).

Another study in Asia found that how parents raise their children affects how the children think about themselves and the world. Parenting associated with more negative schemas, such as Authoritarian and Permissive parenting, affects how likely these children are to feel depressed (Nia et al.). In Iran, researchers also found that feeling abandoned by one's mother can explain why some people become depressed (Nia et al.). In India, perceived abandonment in childhood and being raised with strict conservative beliefs on how children should behave can explain why some people become depressed because of how their fathers raised them (Nia et al.).

One notable study involving 1966 junior high school students in China examined the relationship between adolescent depression and parenting styles (Zhang et al.). The results revealed that depression in junior high school students was negatively associated with permissive and authoritative parenting (i.e., parental care), and positively associated with neglectful (i.e. parental indifference) and authoritarian (i.e., parental overprotection) parenting (Zhang et al.). parental care was associated with a reduced risk of depression in junior middle school students, while parental indifference and overprotection were associated with an increased risk of depression (Zhang et al.). The study also highlighted differences in depression rates among students based on gender, age, and parenting styles, emphasizing the need for tailored education and intervention strategies for junior high school students (Zhang et al.).

Overall the examined research studies had similar results indicating that Authoritarian and Neglectful Parenting were correlated with higher rates of depression and Bipolar Disorder.

### **Future Directions**

In this paper, the relationship between parenting styles and mood disorders was explored. While sufficient research explored the correlation between parenting styles and major depressive disorder and bipolar disorder, there is a gap in the literature regarding the relationship between parenting styles and less common mood disorders, such as dysthymia, cyclothymia, and substance-induced mood disorders. This body of research would also benefit from longitudinal studies to show how these disorders change over time. In the future, it would be advantageous for research to dive deeper into these connections in order to develop a deeper understanding of how environmental and family factors influence the emergence of mood disorders.

Additionally, parenting styles can vary across cultures and regions. The body of literature regarding parenting styles and the development of mood disorders would benefit from the expansion of research to include cultural differences in parenting styles as it could aid with the



creation of a support system for the children affected. Although these relationships would need to be examined further, prevention and intervention may benefit families if the support system is not only for the parents but the children as well.

While the relationship between parenting styles and the development of mood disorders was explored for this paper, the understanding of this relationship can be deepened by future intervention research. Additionally, researchers could partner with social program developers to create and explore the efficacy of a comprehensive parental support system to enable parents to learn effective parenting techniques and comprehend how their parenting approach impacts their children. This support system could include all parenting styles, but particularly authoritarian and permissive parenting styles, as the research included in this paper has identified a relationship between these styles and mood disorders. Emphasizing these would be a significant step forward in promoting mental health and well-being among children and their families.

## Works Cited

- Diagnostic and statistical manual of mental disorders: DSM-5-TR*. (2022). American Psychiatric Association Publishing.
- Adubale, Andrew A. "Parenting Styles as Predicators of Anxiety and Depression of In-School ..." *Taylor & Francis Online*, 18 Sept. 2017, [www.tandfonline.com/doi/abs/10.1080/18146627.2016.1264864](http://www.tandfonline.com/doi/abs/10.1080/18146627.2016.1264864).
- Dattani, Saloni, et al. "Mental Health." *Our World in Data*, 20 June 2023, [ourworldindata.org/mental-health](http://ourworldindata.org/mental-health).
- Ebrahimi, Loghman, et al. "Attachment Styles, Parenting Styles, and Depression - International Journal of Mental Health and Addiction." *SpringerLink*, Springer US, 9 June 2017, [link.springer.com/article/10.1007/s11469-017-9770-y](http://link.springer.com/article/10.1007/s11469-017-9770-y).
- Khajouei Nia, M., Sovani, A., & Sarami Forooshani, G. R. (2014, December 15). *Exploring correlation between perceived parenting styles, early maladaptive schemas, and depression among women with depressive symptoms in Iran and india- role of early maladaptive schemas as mediators and Moderatos*. Iranian Red Crescent medical journal. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4341346/>
- McIntyre, Roger S., et al. "Bipolar Disorders." *The Lancet*, vol. 396, no. 10265, 2020, pp. 1841-1856, [https://doi.org/10.1016/S0140-6736\(20\)31544-0](https://doi.org/10.1016/S0140-6736(20)31544-0). Accessed 28 Sept. 2023.
- McLeod, Bryce D., et al. "Examining the Association between Parenting and Childhood Depression: A Meta-analysis." *Clinical Psychology Review*, vol. 27, no. 8, 2007, pp. 986-1003, <https://doi.org/10.1016/j.cpr.2007.03.001>. Accessed 28 Sept. 2023.
- "Any Mood Disorder." *National Institute of Mental Health*, U.S. Department of Health and Human Services, [www.nimh.nih.gov/health/statistics/any-mood-disorder#:~:text=Prevalence%20of%20Any%20Mood%20Disorder%20Among%20Adults,-Based%20on%20diagnostic&text=An%20estimated%2021.4%25%20of%20U.S.,some%20time%20in%20their%20lives](http://www.nimh.nih.gov/health/statistics/any-mood-disorder#:~:text=Prevalence%20of%20Any%20Mood%20Disorder%20Among%20Adults,-Based%20on%20diagnostic&text=An%20estimated%2021.4%25%20of%20U.S.,some%20time%20in%20their%20lives). Accessed 28 Sept. 2023.
- "Bipolar Disorder." *National Institute of Mental Health*, U.S. Department of Health and Human Services, Feb. 2023, [www.nimh.nih.gov/health/topics/bipolar-disorder](http://www.nimh.nih.gov/health/topics/bipolar-disorder).
- Rostami, M., & Saadati, N. (2018, August 10). *Role of maternal parenting styles in predicting oppositional defiant, behavior, conduct, mood, and separation anxiety disorders among students*. Journal of Research and Health. [http://jrj.gmu.ac.ir/browse.php?a\\_id=1038&sid=1&slc\\_lang=fa](http://jrj.gmu.ac.ir/browse.php?a_id=1038&sid=1&slc_lang=fa)
- Zhang, C., X. Huang, J. Xue, X. Hao, L. Chen, L. Zhang, M. Jin, and Y. Xing. "Relationship Between Depressive Mood and Parenting Style of Junior High School Students and Educational Countermeasures". *International Journal of Education and Humanities*, vol. 6, no. 3, Jan. 2023, pp. 61-65, doi:10.54097/ijeh.v6i3.4182.

# **Type 1 Diabetes in Children: Affect on Cognition and Biotechnological Solutions By Shiksha Anand**

## **Abstract**

Type 1 diabetes in children is becoming increasingly prominent. Glucose is a crucial source of energy for the brain which enables the building of cerebral structures in a child's developing brain. As a result, the glycemic extremes of diabetes adversely impact children's brain structure, including decreasing gray matter and white matter volumes which are still under development in adolescence. Furthermore, earlier onset and frequent occurrences of hypoglycemia in children can increase the child's vulnerability to cognitive impairment, including psychomotor function, attention, and memory. However, there is a compensatory function in the brain's default mode network that attempts to prevent further damage in certain brain regions. As a result of these effects of type 1 diabetes on children, new biotechnological solutions are being researched to find safe and efficient ways to limit glucose fluctuations or prevent a longer duration of such fluctuations, consequently protecting children's cognitive function. This literature review focuses on cognitive impairment in children with type 1 diabetes and analyzes six major components, including glucose in the brain, fluctuations in glucose, and diabetes' impact on psychomotor function, attention, memory, and biotechnological solutions. In order to evaluate various previous papers, multiple databases were searched under the context of type 1 diabetes in children and cognitive impairments of this condition. The papers cited in this review consist of original research articles and literature reviews from PubMed, National Institutes of Health (NIH), and UCI databases.

*Keywords:* type 1 diabetes, hypoglycemia, hyperglycemia, cognitive impairments, biotechnological solutions, psychomotor function, attention, memory

## **Introduction**

Type 1 diabetes is an autoimmune reaction in which the pancreas does not produce insulin, resulting in dysglycemia. Glucose is an essential resource required for brain maturation in children. Thus, extreme fluctuations in glucose levels could lead to impairment in children's cognitive function due to their brain vulnerability during the developmental stages. As a result, brain metabolism is critical in maintaining stability as glucose fuels the brain's neurons and cells. The prevalence of type 1 diabetes in children aged between 0 and 19 years has risen from 2001 to 2009 (Chiang et al., 2018). In particular, the SEARCH for Diabetes in Youth study recorded a 21.1% rise in diabetes in youth; therefore it is vital to conduct research on the nature of type 1 diabetes in children due to its increasing prominence. Although severe hypoglycemia and hyperglycemia can lead to persistent cognitive disorders in type 1 diabetic pediatric patients, there is a dearth of evidence of type 1 diabetes in children and brain function. Additionally, diabetes has a debilitating impact on children and there is a need for on-hand immediate devices to prevent such fluctuations. Therefore, this paper aims to provide an overview of these topics.

Specifically, it will delve into the role of glucose in brain functions and the impact of type 1 diabetes on psychomotor function, attention, and memory as a result of abnormal blood sugar levels with a focus on the current areas of development in the field of biotechnology for solutions. Ultimately, this review aims to emphasize the correlation between type 1 diabetes and brain activity in children while addressing the new biotechnology solutions used for treatment.

## **Methods**

The PubMed, National Institutes of Health (NIH), and UCI databases were searched using the following combinations of keywords: type 1 diabetes in children, hypoglycemia, hyperglycemia, glucose in the developing brain, and cerebral function. To be included in the following literature review, papers focused on the role of glucose on brain functions, the impact of diabetes on young children with a focus on cognition as well as upcoming technologies to prevent cognitive impairment from diabetes. Additionally, the cited paper includes context to understand the various parts of the brain. The papers included in this study were published from the year 2005 to 2023; thus, including foundational knowledge on diabetes as well as updated research. Furthermore, the published papers also include literature reviews on type 1 diabetes. Excluded papers did not include diabetes's applications to children or provide complete access to the paper.

## **Glucose in the brain–*Glucose***

Glucose is a vital source of energy for the brain, thus impacting ATP production, oxidative stress management, and synthesis of neurotransmitters, neuromodulators, and structural components (Dienel, 2019). As a result, the intake and breaking down of glucose can affect cell signaling and brain states such as sleep or arousal (Nadim & Bucher, 2015). A study that tested the cognitive status of diabetic subjects by inducing hypoglycemia resulted in increased lethargy, stupor, and coma with extended periods of hypoglycemia (Dienel, 2019). Thus, glucose plays an important role in energizing the brain functions. Glucose is transported into cells and nervous tissues through the glucose transporters known as GLUT (Cacciatore et al., 2022). These transporters can be affected by the external factors of hyperglycemia, hypoglycemia, and an increased demand for glucose from the brain, therefore altering the expression of the GLUT transporters. Secondly, as the transportation of glucose in neurons is not affected by insulin regulation, neurons can increase their concentration of glucose based on the available concentration of glucose in their surrounding, thus leaving the brain more susceptible to damage. Essentially, if neurons have higher concentrations of glucose available in their extracellular environment, they can uptake more glucose which leaves the brain at risk for damage. Additionally, a child's brain requires more than 20-25% of the body's total glucose levels; thus, it can be safe to infer that a developing brain may be at higher risk of damage due to the neuron's independence from insulin and a higher presence of glucose in the brain. A child's demand for brain glucose is clear; however, due to the highly invasive methods of determining glucose levels and glucose consumption in the brain, there is a lack of data on children's glucose activity in the

brain. While children certainly have an increase in glucose consumption than adults, children at different age levels have varying usages of glucose in distinct regions of the brain. Lastly, as glucose levels rise, the blood-brain barrier becomes increasingly permeable, allowing the entry of substances that are harmful to not only the central nervous system but also the cellular structure involving the rearrangement of membranes. This phenomenon could even lead to the diagnosis of type 1 diabetes in individuals. Therefore, stable glucose levels are critical to maintaining adequate brain functions in children.

### ***Aerobic glycolysis***

Glycolysis, which is the breakdown of glucose for ATP, also occurs under sufficient oxygen conditions; this phenomenon is known as aerobic glycolysis (Cacciatore et al., 2022). Generally, oxidative metabolism pathways are preferred by the body to produce ATP unless there is a disruption in oxygen supply. However, occurrences of aerobic glycolysis indicate that glycolysis is not limited to low-oxygen levels. Aerobic glycolysis is also preferred as the primary pathway in multiple fast-growing single-cellular organisms and is seen in cancer cells, which have high growth rates. Thus, aerobic glycolysis is prevalent in rapidly growing organisms. Similarly, children's rapidly developing brains favor aerobic glycolysis, which explains the increased use of oxygen in children's brains. Another characteristic of aerobic glycolysis is that it increases glucose consumption to carry out the required reactions for the growth of cells; thus, children have an increased glucose consumption in order to build their cerebral structures. However, high aerobic glycolysis could negatively affect neural pathways and be associated with a higher risk of pathological hallmarks (Chen et al., 2021). While aerobic glycolysis carries out positive functions such as biosynthesis and rapid production of ATP, it also increases vulnerability to amyloid- $\beta$  deposition which is a key feature in neurodegenerative diseases. Therefore, the greater prevalence of aerobic glycolysis in children could harm their neurological functions in the long run. However, there is an optimized wiring in high aerobic glycolysis regions that reduces this vulnerability in those brain regions. Further research must be conducted to understand the relationship between aerobic glycolysis and the brain's structural connections which is known as the connectome.

### **Fluctuations in Glucose**

Since children's brains are still developing, fluctuations in glucose levels including severe hypoglycemia and hyperglycemia in type 1 diabetic children can significantly alter their brain structure and neurocognitive function (Nevo-Shenker & Shalitin, 2021). Furthermore, longer durations of severe hypoglycemia can increase the potential for brain injury (Goyal & Raichle, 2019). In a developing brain, there is an increase in the total gray matter (GM) and white matter (WM) volumes as well as an increase in brain glucose consumption (Nevo-Shenker & Shalitin, 2021). Gray matter consists of the outermost layer of the brain (Mercandante & Tadi, 2023). This area has a high concentration of neurons present, which are primarily responsible for processing and releasing information through the white matter's axon signaling. An increased density in

gray matter enables high processing and increased mental development for an individual. As a result, damage in gray matter or a decrease in gray matter volume can result in cognitive impairment. Additionally, HbA1c levels and white matter express a strong correlation, signifying that higher blood glucose levels lead to lower cognitive function in children (Nevo-Shenker & Shalitin, 2021). Furthermore, there is a negative correlation between the gray and white matter volumes and glycemic levels in children (Cacciatore et al., 2022). Results indicated that consistent and severe hypoglycemic events lowered the gray matter and white matter volumes in the brain, thus impairing the overall cognition in children (Nevo-Shenker & Shalitin, 2021). However, as the brain matter volumes must be recorded during a severe hypoglycemic event, there is a lack of data clearly indicating a decrease in white matter volume from glycemic extremes. Similar to the impact of hypoglycemic events, hyperglycemia studies depicted an adverse effect on type 1 diabetic children's visual-spatial ability and memory tasks. Moreover, an earlier onset of type 1 diabetes in children led to poorer overall intellectual and informational processing as compared to children with a later onset of type 1 diabetes, indicating a relationship between cognitive function and glycemic extremes. This relationship between the earlier onset of type 1 diabetes and a more drastic change in cerebral function is also supported by Cacciatore et al. (2022). As a result, if a child had severe glycemic events before the age of five, then the child would be more likely to have lower memory and intelligence levels than of a child who did not experience such glycemic events at that age (Seaquist, 2017). Additional studies and research are required to determine the prolonged effects of hypoglycemia and hyperglycemia on cognition in children (Nevo-Shenker & Shalitin, 2021).

### **Diabetes' impact on psychomotor function**

The psychomotor function involves cognitive tasks such as attention and problem-solving as well as physical movement such as motor responses. The white matter in the brain involves the cognitive domains of information processing, psychomotor function, visuoconstructive ability, and mental flexibility (Seaquist, 2017). As a result, a decrease in white matter function would most likely affect those cognitive functions. 25 adults were tasked to perform the Rey-Osterreith Complex Figure Drawing test, a test that measures the visuoconstructive abilities of an individual. The results indicated a lower performance in the adults with diabetes while noting correlations with lower white matter microstructural integrity. Additionally, lower levels of white matter microstructural integrity indicated a decline in the cognitive domains mentioned above. While this study was performed on adults, it could be inferred that children with type 1 diabetes would likely have similar results from a decrease in white matter volumes. Furthermore, since children with type 1 diabetes have lower white matter volumes, it is possible that children would have more of a drastic effect on their cognition as compared to the adult participants in the previously mentioned study. In another study by the Epidemiology of Diabetes Intervention Complication (EDIC), participants with type 1 diabetes at a mean age of 27 performed several cognitive tests, and their HbA1c values were recorded 18 years later (Moheet et al., 2015). The results indicated that higher HbA1c values (greater than 8.8%) meant a moderate decline in

psychomotor abilities and motor speed, while lower HbA1c values (less than 7.4%) showed better psychomotor abilities. Therefore, since higher HbA1c values indicated high blood glucose in diabetic individuals, type 1 diabetes did impact adversely on psychomotor function. Adults with type 1 diabetes were more likely to have a higher decline in psychomotor function as they age as compared to adults without diabetes. Nevertheless, it was worth noting that there was a lack of data on the impact of type 1 diabetes on the psychomotor function of children as many studies combined analyzing psychomotor function with an aging population with or without type 1 diabetes.

### **Diabetes' Impact on Attention**

Children with type 1 diabetes tended to have lower performance on sustained attention tasks than their diabetic peers; thus, attention was affected by type 1 diabetes (Nevo-Shenker & Shalitin, 2021). The default mode network (DMN) is linked to memory and executive functions and includes the anterior cingulate cortex and the posterior cingulate cortex which are both related to attention processes (Moheet et al., 2015). A DirecNet study involving type 1 diabetic participants and nondiabetic participants (control group) highlighted that there was greater activation in the executive control regions in the diabetic peers while they performed attention-related tasks (Nevo-Shenker & Shalitin, 2021). The executive control region was responsible for tasks involving attention and memory. The amount of activation in the executive control regions showed a correlation with deactivations in the posterior cingulate cortex. Thus, it could be analyzed that the higher activation of certain regions of the brain served as a compensatory function to counteract the impairments in the default mode network of type 1 diabetic brain. As a result, the DirecNet study concluded that the type 1 diabetic participants had equivalent cognitive performance as compared to the non-diabetic control group. Another study that used children's MRI confirmed the increased brain activation in certain control regions and concluded that executive control regions' increased activation could counteract the cognitive impairments produced by type 1 diabetes (Cacciatore et al., 2022). Therefore, this counteraction would allow for normal cognitive function in type 1 diabetic children.

### **Diabetes' Impact on Memory Function**

The severity and onset of hypoglycemia were found to have an impact on long-term spatial memory performance (Hershey et al., 2005). A study that included participants aged from 6 years to 18 years, showed a correlation between hypoglycemia frequency and timing in type 1 diabetic children. In particular, if the first episode of hypoglycemia occurred before the age of 5 years with 3 or more severe episodes of hypoglycemia continuing to occur, then the child was more prone to worse memory function. Another study on children conducted by DirecNet analyzes memory function in relation to type 1 diabetes (Nevo-Shenker & Shalitin, 2021). The results produced that children with type 1 diabetes performed worse on the visuospatial working memory tasks while children with an earlier onset of type 1 diabetes displayed a more pronounced effect on their memory skills. Secondly, similar to the activation during

attention-related tasks, there is a higher activation in certain brain regions while performing memory-oriented tasks. However, since children with type 1 diabetes performed worse on memory tasks as compared to the control group, the DirecNet study concluded that the compensatory function was not effective in offsetting the memory-related impairments. As a result, type 1 diabetes and the severity of hypoglycemic events did impact memory function in children.

### **Biotechnological Solutions**

Research on new technologies that prevent cognitive damage in children with type 1 diabetes has been underway. An earlier onset of type 1 diabetes in children suggested an increase in the chances of cognitive dysfunction that would affect the academic involvement of a child (Moheet et al., 2015). Thus, the development of new technologies has been necessary to protect a child's brain and cognition. An additional problem is that children are unable to express glycemic extremes until it may be too late, causing cognitive impairment (Nevo-Shenker & Shalitin, 2021). As a result, glycemic detection technology would also prove helpful in such situations. Technologies including, sensor-augmented pumps (SAP), continuous glucose monitoring (CGM), and continuous subcutaneous insulin delivery are useful solutions to improve glycemic outcomes. The sensor-augmented pumps include a continuous glucose monitor (CGM) and limit the severity as well as the duration of hypoglycemia (Steineck et al., 2017). As a result, if the severity and duration of a hypoglycemia event are restricted early on, then it can be assumed that the brain would experience less damage. Thus, SAP is useful in preventing cognitive damage by limiting severe hypoglycemic episodes. The SAP works by releasing insulin to the body upon a signal of low glucose levels from the CGM sensor to the insulin pump, allowing for automated suspension of insulin delivery (Steineck et al., 2017). CGM systems available include Dexcom G6, Senseonics Eversense, and Medtronic which gather real-time data such as the rate of change in glucose and hypoglycemia and hyperglycemia levels (Sherwood et al., 2020). This data is used to observe and analyze glycemia patterns in the patient. Additionally, the CGM's data can be shared with family members to promptly alert them of an alarming glucose level. Therefore, the CGM is beneficial for children as their parents can be notified when the child's glucose level requires attention, consequently limiting the severity of hypoglycemia and hyperglycemia. Next, insulin pumps, which are also referred to as continuous subcutaneous insulin delivery, track the insulin usage in the body and accordingly adjust the insulin doses. Insulin delivery can be automated to deliver insulin when the blood glucose levels drop below a certain threshold, therefore decreasing the amount of time a diabetic individual is in hypoglycemia. By limiting the duration of hypoglycemia, a type 1 diabetic child's neurocognitive damage is reduced. Thus, insulin pumps maintain and regulate glucose levels which reduce the frequency of severe hypoglycemia (Nevo-Shenker & Shalitin, 2021). Overall, these new technologies efficiently and safely monitor glucose levels and optimize glycemic control in type 1 diabetic children; thus, lessening damage to a child's developing brain and its cognitive functions (Nevo-Shenker & Shalitin, 2021).



## **Conclusion**

This literature review focused on the impact of type 1 diabetes on children's cognitive function. In particular, the review provided an overview on the (1) function of glucose, (2) fluctuations in glucose, (3) T1D's impact on psychomotor function, (4) attention, and (5) memory. Ultimately, it could be concluded that as a child's brain develops, it is more susceptible to cognitive impairments due to extreme and multiple glycemic events. Additionally, this vulnerability of the brain is due to the changes in a child's gray and white matter development. An earlier onset of such abnormal glucose levels indicated an overall lower cognitive function in children, including memory function. Type 1 diabetes negatively impacted psychomotor function in diabetic patients with higher HbA1c values. It is worth noting that this decline in psychomotor function has not been explicitly tested for children. Research showed a negative correlation between the severity and onset of hypoglycemia and performance on memory tasks. As a result, children with an earlier onset of hypoglycemia with multiple occurrences tended to perform worse on visuospatial memory tasks. Similarly, there is a negative effect of diabetes on children's attention function; however, research indicated that there is a compensatory function that prevents further impairments in the default neural network of type 1 diabetic individuals. These findings highlighted the importance of developing prevention and protection devices for type 1 diabetic children as diabetes can negatively impact children's academic performance. Sensor-augmented pumps, continuous glucose monitors, and insulin pumps are upcoming technologies to prevent cognitive damage following longer durations of glycemic extremes. These technologies are efficient in automatically regulating blood glucose levels in children who are often unaware of their glucose levels. Nevertheless, there is room for further research on the long-term benefits of these devices as well as other methods to prevent the debilitating consequences of diabetes.

## Works Cited

- Cacciatore, M., Grasso, E. A., Tripodi, R., & Chiarelli, F. (2022). Impact of glucose metabolism on the developing brain. *Frontiers in endocrinology*, 13, 1047545. <https://doi.org/10.3389/fendo.2022.1047545>
- Chen, Y., Lin, Q., Liao, X., Zhou, C., & He, Y. (2021). Association of aerobic glycolysis with the structural connectome reveals a benefit-risk balancing mechanism in the human brain. *Proceedings of the National Academy of Sciences of the United States of America*, 118(1), e2013232118. <https://doi.org/10.1073/pnas.2013232118>
- Chiang, J. L., Maahs, D. M., Garvey, K. C., Hood, K. K., Laffel, L. M., Weinzimer, S. A., Wolfsdorf, J. I., & Schatz, D. (2018). Type 1 Diabetes in Children and Adolescents: A Position Statement by the American Diabetes Association. *Diabetes Care*, 41(9), 2026–2044. <https://doi.org/10.2337/dci18-0023>
- Dienel G. A. (2019). Brain Glucose Metabolism: Integration of Energetics with Function. *Physiological reviews*, 99(1), 949–1045. <https://doi.org/10.1152/physrev.00062.2017>
- Goyal, M. S., & Raichle, M. E. (2018). Glucose Requirements of the Developing Human Brain. *Journal of pediatric gastroenterology and nutrition*, 66 Suppl 3(Suppl 3), S46–S49. <https://doi.org/10.1097/MPG.0000000000001875>
- Hershey, Perantie, D. C., Warren, S. L., Zimmerman, E. C., Sadler, M., & White, N. H. (2005). Frequency and Timing of Severe Hypoglycemia Affects Spatial Memory in Children With Type 1 Diabetes. *Diabetes Care*, 28(10), 2372–2377.
- Nadim, F., & Bucher, D. (2014). Neuromodulation of neurons and synapses. *Current opinion in neurobiology*, 29, 48–56. <https://doi.org/10.1016/j.conb.2014.05.003>
- Nevo-Shenker, M., & Shalitin, S. (2021). The Impact of Hypo- and Hyperglycemia on Cognition and Brain Development in Young Children with Type 1 Diabetes. *Hormone research in paediatrics*, 94(3-4), 115–123. <https://doi.org/10.1159/000517352>
- Mercadante, A. A., & Tadi, P. (2023). *Neuroanatomy, Gray Matter*. In StatPearls. StatPearls Publishing.
- Moheet, A., Mangia, S., & Seaquist, E. R. (2015). Impact of diabetes on cognitive function and brain structure. *Annals of the New York Academy of Sciences*, 1353, 60–71. <https://doi.org/10.1111/nyas.12807>
- Seaquist E. R. (2015). The Impact of Diabetes on Cerebral Structure and Function. *Psychosomatic medicine*, 77(6), 616–621. <https://doi.org/10.1097/PSY.0000000000000207>
- Sherwood, J. S., Russell, S. J., & Putman, M. S. (2020). New and Emerging Technologies in Type 1 Diabetes. *Endocrinology and metabolism clinics of North America*, 49(4), 667–678. <https://doi.org/10.1016/j.ecl.2020.07.006>
- Steineck, I., Ranjan, A., Nørgaard, K., & Schmidt, S. (2017). Sensor-Augmented Insulin Pumps and Hypoglycemia Prevention in Type 1 Diabetes. *Journal of diabetes science and technology*, 11(1), 50–58. <https://doi.org/10.1177/1932296816672689>

# **An Analysis of Women and Racial and Ethnic Minorities in American Adventure Films By Madeleine Yoon**

## **Abstract**

This paper explores how racial/ethnic and gender minority groups have been portrayed in film and assess how these portrayals or lack thereof is indicative of their current social value. People who are not valued in society are not represented on screen which continues to disenfranchise them even more. With a concentration on films in the adventure genre, the study will assess 4 of the most popular, and thus most potentially influential, PG or PG-13 adventure films from 2010 - 2023 from IMDb's top 30 adventure films database. Using a variety of tests that measure representation of race and gender as well as drawing from the social cognitive theory and Alvarado's theory of ethnicity and racial stereotypes, this study seeks to explain the relevance and consequences of problematic, stereotypical, or omitted portrayals of minority groups and how such messages can translate into the public consciousness. As these findings indicate a harmful situation, there is a need for policy solutions to foster more accurate and diverse representations in film.

## **Introduction**

Since the advent of television in the early 1900s, film has become a popular form of American entertainment for all ages with the genre of adventure being the highest grossing since 1995 (Statista, 2023). However, many have raised concerns over the portrayals of minority groups on the small screen, highlighting how they are inaccurately represented or their presence omitted entirely. With adventure films only gaining more popularity along with the rise of big movie franchises such as Marvel, Star Wars, and Indiana Jones, these concerns only continue to grow. Despite making up 43.1% of the U.S. population in 2022, only 33.3% of streaming film leads were people of color, which is less than proportionate representation (UCLA, 2023). Similarly, women constituted only about a third of on-screen protagonists in 2022 (Lauzen, 2022). Today, adventure films are the highest grossing movie genre in the North American box office. This genre of film allows for new worlds to be built and unique events to be created, yet as much as films are a tool for entertainment and fictional work, they are often a reflection of society. With this in mind, we must consider why some groups are so underrepresented in film and what can be done to improve the number of accurate portrayals. This paper will review and document the representation of gender and racial/ethnic minorities in action/adventure films that are intended for audiences under 18 years old, as well as identify any stereotypes, omissions, or problematic portrayals of the same groups.

## **Literature Review**

When groups are more socially valued in the real world, it is reflected on screen. People who are not socially valued tend to be underrepresented on screen which in turn continues to disenfranchise them further. In other words, representation on screen is indicative of a group's

current social value but also works to increase or decrease a group's social value. As technology continues to evolve and society becomes more exposed to media, what we see on screen begins to affect our own beliefs and perceptions of the world. This cultivation theory assumes that continuous exposure to the messages films and other forms of media posit can suggest how it may be more desirable to be a part of one social group over another (Klein & Shiffman, 2018). When a group is omitted from on screen representations, that can also be indicative of their social power and status. When the media fails to represent a group of people, it is called symbolic annihilation, and they can become disregarded in the minds of the larger public consciousness (Coleman & Yochim, 2008). Symbolic annihilation is already an existing problem with representations of racial/ethnic minorities and women on the small screen who are not only often omitted from media but also trivialized and condemned. Only 33% of films had a female protagonist in 2022, and women only made up 37% of all speaking characters while men made up 63% in 2022. Of those speaking characters, the simple majority of them (64.2%) were white (Lauzen, 2022). Despite these statistics, however, women have been gaining greater representation in terms of sheer screen time over the past 20 years in general. Yet, these female characters are still filled with problematic portrayals and harmful stereotypes. Domesticated roles like mothers and caretakers or stereotypically "feminine" traits continue to be overused today: "Women are seeing greater representation in roles valued for their intelligence, their strength, and their independence more frequently in later films than in earlier films, but . . . they are still not as well-rounded, or as important, as the men" (Murphy, 2015). It was also found that the goals of female characters were primarily personal life-related, while that of men were primarily work-related (Lauzen, 2022). A reason for this may be due to the fact that white men dominate the film industry with only 23.6% of producers, directors, and writers being women (Smith, Pieper, & Wheeler, 2023). Especially in the realm of science fiction or adventure movies, female characters have been developed in order to appeal to a male audience, with an emphasis on physical characteristics: "The importance to outer appearance has been underscored by the fact that often women have been shown to dress provocatively and belonging to a younger age category" (Basu, 2005). Despite the fact that adventure movies are popular with over 85% of women, this genre of film tends to encourage hyper-masculinity, portraying their male characters as aggressive and decisive while their female characters are more empathetic and affectionate. The demographic and behavioral attributes of female characters in sci-fi movies are also jarringly similar. They are likely to be portrayed as white and slim, having no or limited occupation and rarely exhibiting physical aggression (Basu, 2005). In general, the on-screen depictions of women tend to generalize them as overly emotional, dependent on others, and less ambitious than their male counterparts (Murphy, 2015). In female protagonists of adventure movies, they can appear as independent as strong 'girl power' icons, but this quality is often undermined by their desire for a family or relationship, thus confining them to domesticated roles once again. Additionally, an emphasis on physical attractiveness persists by depicting strong females as seductive and placing them in the context of male desire.

Women of color, especially, tend to be objectified and underdeveloped in film. In East Asian women, orientalist tropes have been normalized in their on-screen portrayals. American films often mythologize and otherize East Asian characters, playing into two common archetypes: the China Doll and the Dragon Lady. The China Doll constructs the East Asian woman as a meek and submissive character, often portraying her as a sex worker, slave girl, or prostitute. By portraying women in such a way, it paints a fantasy of fragile, powerless Asian damsels in distress that white characters become infatuated with and motivated to save. This trope often comes to life in the form of a tragic lover, in which the East Asian character “knows herself as the last priority of a White man’s life, and is content with simply fulfilling his desires as long as he wants her. Her role, as she only exists as long as his desire for her exists, is service and obedience, and when it is time for him to return to his superior White world, she must disappear without a trace as a last task to ease his guilt and purge his sin” (Lee, 2018). On the other side of the spectrum is the Dragon Lady who is characterized as a cold, heartless yet still seductive woman who may challenge and resist the white characters but eventually submit to white dominance. The Dragon Lady is often sexualized, dehumanized, and overpowered by the white character, reinforcing dominance of the West. These two overused archetypes construct a dangerous and completely inaccurate dichotomy that “forces [East Asian women] to be either soft and docile, or hard and aggressive, without space for anything complex or human in the middle ground” (Lee, 2018).

Much like the meek China Doll stereotype, the white savior trope is also extremely prominent in the on-screen representations of characters of African descent. There seems to be a hyper-focus on white female characters uplifting and providing for black characters. While this may seem like a touching instance of inclusivity and kindness, it also “systematically erases, limits, and forecloses the potential and presence of black womanhood and caretaking” (Deutsch, 2020). White people are so often portrayed as saviors and heroes while people of color are depicted as victims or villains. People of color also tend to be other-ized on screen with regards to weight, height, dress, and other physical or behavioral attributes. Middle Eastern culture, for example, is often stereotyped as mysterious and enchanting. Depictions of the Middle East tend to portray boundless, scorching desserts or chaotic, bustling markets (Nashef, 2013). While these may be aspects to life in the Middle East, they are certainly not all there is. However, film tends to ignore their nuanced and multi-faceted culture and dominates the screen with static, flat portrayals. Despite the fact that movie watchers in America consist of a diverse group of people, films fail to represent that. In 2022, 61.7% of all speaking characters were white, with only 13.4% black, 15.9% Asian, 5.2% Hispanic/Latino, and 3.8% other (Smith, Pieper, & Wheeler, 2023).

Both women and racial minorities are underrepresented in film. According to Social Cognitive theory, this is specifically harmful as we actively learn while consuming media. What we see on screen helps us develop mindsets and perceptions of the real world. Social Cognitive Theory tells us that people “look to relationships presented in film to learn what to expect from real life-relationships” (Johnson and Holmes, 2009). In other words, the sidelining of women and

characters of color thus insinuates the idea that they are less important, and the generalizations depicted in their on-screen portrayals can be translated into our own views.

## **Methodology**

This study will be based on the examination of content in adventure movies as it is the highest grossing movie genre in the North American box office. Four films will be chosen for this study from IMDb's list of most popular PG and PG-13 rated adventure movies from 2010 to 2023. Being the top films from the highest grossing movie genre, the films in examination are likely to be the most popular and thus the most potentially influential. Due to fiscal constraints and lack of availability for the examiner, the films chosen for the study sample had to exceed the first 4 on IMDb's list, but all receive a ranking of above the top 25. The films chosen for the study were 2014 *Interstellar* (rank 7), *Inception* (rank 12), 2021 *Dune* (rank 19), and 2018 *Mission Impossible - Fallout* (rank 21). Movies rated PG or PG-13 were chosen as they are intended for younger audiences, meaning it is likely to be influential on the viewers' beliefs and attitudes as they are going through early developmental stages. Only movies from the time period 2010-2023 were chosen to ensure an up to date analysis. The primary questions examined by this study were:

1. How are racial/ethnic and gender minority groups currently represented in action/adventure movies? and
2. What are the most salient problems in these portrayals?
3. What are the key approaches to ensuring accurate and inclusive representations of gender and racial/ethnic minority groups in American film?

To analyze the representations of racial, ethnic, and gender minorities, each film went through the five tests.

1. The Bechdel test was used to measure gender bias. A film would be awarded a pass score if all of the following indicators were observed: (1) The movie must have two female characters (2) who speak to each other (3) and their discussion is of something other than a man.
2. The Duvernay test was used to measure racial/ethnic bias. A film would be awarded a pass score if all of the following indicators were observed: (1) The story has at least two people of color that have complex character, meaning they have rich lives that are not solely in relation to white people. They also must not be in a romantic relationship with each other. (2) Characters of color must be given names. (3) Characters of color must have speaking roles and their discussions can not center around defending a white person.
3. The Ko test was used to measure representation of women of color. A film would be awarded a pass score if all of the following indicators were observed: (1) There's a non-white, female character (2) who speaks in 5 or more scenes (3) and speaks English.

4. The Waithe test was used to measure representation of black women. A pass score would be awarded if all of the following indicators were observed: (1) There is a black woman (2) who is in a position of power (3) and is in a healthy relationship with her partner.
5. The Villalobos test was used to measure the representation of Latina women. A film would be awarded a pass score if all of the following indicators were observed: (1) The film has a Latina lead. (2) The lead or another Latina character is shown as professional or college educated, (3) speaks in unaccented English, (4) and is not sexualized.

It is important to note that all of these tests are quantifiable measures and only account for the mere screen time or presence of gender and racial/ethnic minorities. While these tests may be a good indicator of the representation of these groups, they do not record the accuracy or inclusiveness of every portrayal completely. To provide a more nuanced and thorough analysis of the representation of gender and racial/ethnic minorities, multiple theories were used as a framework for further examination of the films. The Social Cognitive Theory raises the question of if women were portrayed in a hyper-traditional manner or if gender stereotypes were reinforced throughout the film with regards to personality, abilities, and attitudes. Alvarado's theory of ethnicity and race examines if specific racial groups are portrayed as exotic or other, vulnerable victims, dangerous or immoral, and/or a subject of mockery. Finally, this study examined findings from available research literature to identify potential policy ideas and solutions to foster more accurate representations of gender and racial/ethnic minorities.

## **Results**

To analyze the representation of women and racial/ethnic minorities in American adventure films, four of IMDB's most popular movies were analyzed. Below is a summary of all the movies that were reviewed.

*Interstellar* (2014) centers around a protagonist Joseph Cooper who embarks on a journey through space and time in order to find a "Planet B" after Earth has become uninhabitable due to extreme dust pollution. As he and a team of researchers— including genius scientist Amelia Brand – slip through space for just a couple of days, years pass back on Earth. Cooper's young daughter (Murph) grows up into a bright woman, working at NASA with the same people that sent her father to space in order to find a way to preserve the human race.

*Inception* (2010) centers around Cobb who enters people's dreams and steals secrets from their subconscious. Cobb gets into trouble because of his work, is forced to abandon his family and longs to be reunited with them. This opportunity comes when a businessman, Saito, enlists Cobb to implant an idea into his business rival. In return, Saito will ensure Cobb's safe passage back to his family. Cobb recruits a team of chemists, other extractors, and architects (including grad student Ariadne) for this job. However, Cobb's past haunts him, making it much more difficult for the mission to be successful.

*Dune* (2021) follows protagonist Paul Atreides, born into nobility. When his father, Duke Leto, is given authority over the desert planet Arrakis by order of the Emperor, they are thrust

into a war for the planet’s priceless, powerful spice. Paul’s father is killed by the House of Harkonnen, leaving him and his mother (Lady Jessica) to fend for themselves while mysterious visions of a Fremen girl plague his dreams.

Mission Impossible - Fallout (2018) is the sixth movie of the Mission Impossible series following Ethan Hunt. After a series of events gone wrong, Hunt is faced with the decision to choose between saving his teammate or retrieving the dangerous, world threatening plutonium cores. Ultimately, the cores end up in the wrong hands and Hunt and his team must work together with an unfamiliar Central Intelligence Agency (CIA) agent to get them back.

All four movies were assessed for gender and racial bias. Results show that *Interstellar* (2014), *Inception* (2010), and *Mission Impossible - Fallout* (2018) failed all five tests while *Dune* (2021) only passed the Bechdel and Ko tests. Figure 1 outlines the results of this analysis.

	<b>Gender</b>	<b>Race</b>	<b>Intersectional</b>	<b>Intersectional</b>	<b>Intersectional</b>
	<b>Bechdel Test</b>	<b>Duvernay Test</b>	<b>Ko Test</b>	<b>Villalobos Test</b>	<b>Waithe Test</b>
Interstellar	Fail	Fail	Fail	Fail	Fail
Inception	Fail	Fail	Fail	Fail	Fail
Dune	Pass	Fail	Pass	Fail	Fail
Mission Impossible - Fallout	Fail	Fail	Fail	Fail	Fail

Fig 1: Test results for all four movies, analyzing gender and racial bias in the films.

### Analysis of Gender Bias in Film

The Bechdel test was used to measure gender bias in film. A film would be awarded a pass score if there are two female characters who speak to each other and their discussion is of something other than a man. *Interstellar* (2014) depicts multiple essential female characters including Murphy and Brand, both of who are portrayed as highly intelligent women and integral in the space mission and colonizing a second planet. However, the two never talk to each other with their closest form of contact being a video message sent by Murph, informing Brand that her father has passed away. A conversation between Murph and Lois (her sister in law) is also depicted but the main topic of conversation is about the health of Lois’ son’s lungs. Thus, a fail score was awarded with only 2 out of the 3 criterias observed.

There was a similar result in *Inception* (2010). There are two female characters in the film: Mal and Ariadne. The two characters have a brief conversation in Cobb’s dream about love. However, while the topic of conversation is about love in general, it stems from Ariadne’s



yearning to “try and understand” Cobb (which she states in the conversation) and Mal’s feelings of love toward Cobb. So, it passed only 2 out of 3 criterias and was awarded a fail status.

*Mission Impossible - Fallout* (2018) also failed the test. There are only two women who talk to each other in the film. Ilsa and Jules are depicted whispering things to each other but the topic of conversation between them is never disclosed to the audience.

*Dune* (2021) was the only movie that passed the Bechdel Test as a result of Lady Jessica and Shadout Maples’ brief conversation about a knife.

To provide a more nuanced and thorough analysis of the representation of women, the Social Cognitive Theory was used as a framework for further examination of the films. This theory examines the portrayal of women in a hyper-traditional manner and the reinforcement of gender stereotypes with regards to personality, abilities, and attitudes.

The two characters of Murph and Dr. Brand in *Interstellar* (2014) were analyzed within this framework. Both women are depicted as highly intelligent, committed to the cause of saving the human race. With a background as a biologist at NASA, Dr. Brand joins the Endurance mission team, and she forms a friendship with protagonist Cooper. However, Cooper notices Brand’s hidden feelings towards Wolf Edmunds (a male physicist). After their journey to the first planet, the team must decide between traveling to Dr. Mann’s planet or traveling to Dr. Edmund’s planet. When Dr. Brand proposes a plan of action, Cooper questions whether Dr. Brand comes to that decision based on scientific evidence or if her judgment is clouded by her romantic feelings for Edmunds. Despite Dr. Brand’s explanation, Cooper remains unconvinced and makes an alternative decision. In response to this, Dr. Brand gets up, cries, and leaves the room. In this scene, Dr. Brand is made out to be emotional and irrational for following her heart to Edmund’s planet. These traits are generally perceived as “feminine flaws” and generalize Brand as an overly-sensitive woman who allows romance to undermine her intelligence.

On the other hand, Cooper is depicted as the objective and logical captain who sets her straight. In a similar manner, Murph (Cooper’s daughter) is depicted as another brilliant, yet emotional young woman. When Cooper leaves for his long space trip, Murph is around 10 years old. Upset at her father for seemingly “abandoning” her and her brother, she refuses to say goodbye to him even though both are unsure when or if he will return. Though this reaction is understandable for any child that age, Murph’s grudge towards her father remains throughout the years. While Cooper’s son continuously sends him video messages, Cooper never receives any from his daughter until around 25 years later. Her personality is depicted as stubborn and temperamental, another pair of “feminine flaws” that *Interstellar* (2014) incorporates into the film’s female characters.

However, it is important to note that the film also includes non hyper-traditional portrayals of Murph and Dr. Brand. Both characters are essential to the plot, and their removal would have led to a disappointing ending for the Endurance team and the human race. At the end of the film, it is shown that Murph is able to save the human race. Brand’s ending is a little more ambiguous, but she is shown to have made it to Edmund’s planet, which seems perfectly habitable, making her argument of love not so absurd after all. Even Cooper, who originally

dismissed Brand's opinions, admits that his love for his daughter was the powerful force that drove him to leave the data that allows Murph to save the human race in his watch.

*Inception* (2010) yielded a similar result, depicting intelligent and capable yet also emotional female characters. *Inception* is a male-dominated movie, and the only female characters depicted are Ariadne (an architect recruited by Cobb to construct dreams) and Mal (Cobb's late wife who only exists in his subconscious); the other members of Cobb's crew are male. Though Ariadne is portrayed as a bright young woman and is initially recruited to be an "architect" of their dreams, the other purpose of her character is to be an emotional guidance for Cobb. After following Cobb into one of his dreams, Ariadne learns of his late wife's passing and the guilt he struggles to grapple with, which has impaired his effectiveness on the field. She is the only one who knows how Mal's death continues to haunt him and makes it her personal mission to help guide him through his emotions. In this way, she is depicted as the most emotionally-attuned and maternalistic as she helps him navigate his grief and guilt.

On the other hand, the other male team members have no knowledge of Cobb's internal struggle and are portrayed as very objective and oblivious to Cobb's pain, despite knowing Cobb longer than Ariadne has. In the grand scheme of things, Ariadne's importance to the mission is ultimately overshadowed by her role as Cobb's "emotional caretaker," with most of her screen time shared with the protagonist. Just as Ariadne helps Cobb balance his emotions, Mal is the woman who derails his objectivity and judgment. It is important to note though, Mal is simply a figment of Cobb's subconscious. Before her passing, Mal and Cobb explored the dream-sharing technology together, venturing deeper and deeper into their dreams until eventually getting stuck in Limbo. There, Mal can not distinguish their dreams from reality anymore. After 50 years in Limbo, Cobb urges Mal to come back to the real world but fails to successfully convince her. Thus, he performs inception for the first time, implanting the idea that they were trapped in limbo and not reality. The idea grows and changes Mal's mind, allowing the two of them to escape. This eventually backfires, however, and once Mal and Cobb come back to reality, Mal still continues to believe that they are dreaming. Disoriented and almost mad, Mal comes up with a plan to convince Cobb to commit double suicide with her in order to go back to the real world. By portraying Mal this way, *Inception* plays on the "hysterical woman" stereotype; Mal is depicted as disoriented, crazy, and anxious, all of these feelings stemming from Cobb's manipulation of her mind. Mal creates problems in Cobb's subconscious, and Ariadne helps stabilize his feelings. Both women are not necessarily deemed essential figures to the overall mission, adding a more "emotional" aspect to the film instead.

With regards to female characters in *Dune* (2021), the first woman introduced is Lady Jessica, Paul's mother. She is a powerful woman with the ability of "The Voice," which can control the mind and body of those she commands. From birth, she is trained as a Bene Gesserit—a secret society of powerful women who train to ascend the human race. The Bene Gesserit believe in the Kwisatz Haderach, who would have the ability to bridge space and time. Though told to only bear daughters, Lady Jessica is determined to be the one to produce the Kwisatz Haderach and gives birth to Paul with Duke Leto Atreides. Lady Jessica is undoubtedly

an extremely powerful woman belonging to a society of even more powerful women, but this identity is undermined by her giving birth to Paul. Her quest to bear Kwisatz Haderach requires her to go against her fellow women, give birth to only a son and cultivate him into the chosen one. Thus, her character has some hyper-traditional elements despite her special abilities. Because the big goal of her life is to bear a son and cultivate him into this legendary man, it seems that her identity as a mother overshadows the rest of her character. This split identity between Lady Jessica as Paul's mother and as the Bene Gesserit is brought up in the film as well. Duke Leto Atreides asks Lady Jessica, "If anything happens will you protect our son?" To which Jessica responds, "With my life." However, Leto continues, "I'm not asking his mother. I'm asking the Bene Gesserit." Lady Jessica's character struggles as the time for Paul to ascend to the title of "the One" nears, but her maternal instinct to protect him waives her resolve.

Another influential woman in *Dune* is Chani. Despite opening the film, her character is largely sidelined, as her only screen time is glimpses in Paul's dreams, standing gracefully in the desert with wind blowing in her hair and smiling at him. She is shown in an almost seductive manner, especially when Paul sees himself stabbed in the gut by her after going in for a kiss. This is comparable to Lady Jessica who gives birth to Paul while she is Duke Leto's concubine and the two never marry. Additionally, Lady Jessica initially wanted a son solely to give rise to Kwisatz Haderach. Thus, in this way, both Chani and Lady Jessica are portrayed as women with alternative motives and no healthy, stable relationship.

As the movie comes to a close, we finally meet Chani, and the scene sets Chani and Paul up for some more potential screen time together in the confirmed sequel. However, for most of the film, Chani is only a girl who exists in Paul's dreams and works solely as a motivator and teacher of sorts for him through his journey, showing him around Arrakis and teaching him the ways of the desert. While both Chani and Lady Jessica are major characters in the film, they mainly serve as characters to help Paul reach his full potential.

In the film *Mission Impossible - Fallout* (2018), the women are often seen as "damsels in distress," to which Ethan must come and save. We can see this situation with Ethan Hunt's wife, Julia, who he ultimately divorces due to the fact that being married to her would put her and the rest of the world at risk. Though this plot point was only briefly mentioned in *Mission Impossible - Fallout*, the film still opens up with a scene dedicated to Hunt's conflicted feelings of wanting to keep Julia safe but also wanting to be there for the rest of the world.

This is not to say, however, that all the female characters in *Mission Impossible - Fallout* part in the "damsel in distress" archetype. The other, and perhaps more prominent, female character in the film is Ilsa who proves to be a headstrong, capable assassin. Even towards the end of the film, Julia is depicted as a stronger character, working under pressure to deactivate a bomb, thus, breaking her out of the weak, pitiful character archetype. Overall, *Mission Impossible - Fallout* succeeds in portraying two unique and well rounded female characters in a non hyper-traditional way. While both of them aren't as essential to the plot as Ethan Hunt, they are still extremely important to both the action and emotional aspect of the film, even holding prevalence over the rest of Ethan's male crew. However, this does not change the fact that

*Mission Impossible - Fallout* is a heavily male dominated movie, and the lack of female characters is concerning.

### **Analysis of Racial/Ethnic Bias in Film**

The Duvernay test was used to measure racial/ethnic bias in film. A film would be awarded a pass score if all of the following indicators were observed: (1) The story has at least two people of color that have complex character, meaning they have rich lives that are not solely in relation to white people. They also must not be in a romantic relationship with each other. (2) Characters of color must be given names. (3) Characters of color must have speaking roles and their discussions cannot center around defending a white person. None of the films passed this test.

*Interstellar* (2014) was awarded a fail score despite the fact that there are two characters of color in the film (the school principal and Rommily). Rommily is an African American man and one of the team members on the Endurance mission. He proves to be an intelligent physicist and an integral member of the team. However, the audience fails to gain insight into his life, experiences, or personality past his fear of space. His character also gets limited screen time, which hinders further analysis of his character. The school principal is also an African American man. However, he is not given a name and only has one speaking scene. Thus, the movie failed with only 1 out of the 3 criteria passing.

There are two characters of color in *Inception* (2010) as well: Yusuf the chemist and Mr. Saito who employs Cobb. While both characters have names and speaking roles, Yusuf's character is shown to simply follow Cobb's orders and enrich his life by helping him complete his job. Outside of his skills as a chemist and his "den of sleepers" (where customers come to get sedated and whisked off to dreamland), his character lacks any substantial depth. There is no portrayal or allusion to a family or any aspirations. Even his motivation for joining Cobb's crew is unclear. Throughout the film, his job is only to create sedatives for Cobb's crew and their target so that they can continue dreaming and carry out the mission. His character exists solely to enrich Cobb's life and mission.

Mr. Saito is a wealthy Japanese businessman who employs Cobb with the task of inception. Though he is in a position of power in the real world, inside the dreams he is nicknamed "The Tourist" due to the lack of his extracting experience. In the early stages of the mission, he is shot and eventually dies, falling into a deep dream state called Limbo, and Cobb is forced to save him. Outside of his great financial influence, Mr. Saito's life is kept largely private from the audience. However, his motivations seem to be pure, stating that the world will benefit from the collapse of Fischer's company, as it would prevent the creation of another "superpower" in the energy industry. Because both characters lack any developed storyline, the film did not pass the first criteria and was awarded a fail score.

While there are many Fremen characters in *Dune* (2021) which were classified as people of color, none of these characters were thoroughly developed. Every character of color serves to enrich the journey of the white, male protagonist. Even the major characters of color who do

have names and dialogue, such as Chani and Liet-Kynes, lack depth. No details to their families, backgrounds, or motivations are depicted outside of their relation to their white counterparts. Therefore, the film failed with only 2 out of 3 criteria observed.

*Mission Impossible - Fallout* (2018) also failed the Duvernay test with only 2 out of the 3 criteria passed. The two characters of color are Luther and Erica Sloane. While both have names and substantial dialogue in the film, neither have rich lives outside their relation to Hunt. Especially, Sloane has limited screen time and there is virtually no insight to her background outside her identity as the CIA director.

To further analyze the films, Alvarado's Theory of Race and Ethnicity was used as a framework, examining if specific racial groups are portrayed as exotic or other, vulnerable victims, dangerous or immoral, and/or a subject of mockery.

In *Interstellar* (2014), there is only one character who plays a major role: Rommily, an intelligent black man with a background in physics and a member of the Endurance team. While he is not characterized as exotic, dangerous, or a subject of mockery, Rommily's story is not as developed as fellow team members—Dr Brand and Cooper—and the limited view the audience has of his personality is characterized by his fear of space. Upon their initial takeoff, Rommily is the only team member who is visibly sick and queasy. The screen time Rommily gets is dedicated to his fears while his white, male teammate must then reassure him. By depicting Rommily in this way, *Interstellar* paints him as a victim of sorts, trapped by his own situation.

Using Alvarado's Theory of Race and Ethnicity as a framework, the findings indicated that no specific racial group was characterized as exotic or "other," a subject of mockery, victimized, or portrayed as a threat to society in *Inception* (2010).

In *Dune* (2021), there is a group of people called the Fremen who are a distinct people with common traits including dark skin and bright, blue eyes. While *Dune* never directly comments on their race or ethnicity, it is clear to the audience that they have their own culture, religion, and language. The Fremen is their exact, fictional title, but they have origins tracing to the Middle East. The Fremen inhabit the desert planet Arrakis, which is the only source of spice, an extremely valuable resource that powers intergalactic travel. The spice on Arrakis attracts people from all over the galaxy, and while the rich get richer, the native Fremen are colonized and persecuted. In the way the Fremen's oppression is powered by material wealth, there is quite a lot of allusion to real world colonization through their portrayal. Though this situation may seem to be a depiction of the Fremen as simply weak, vulnerable victims, they are actually quite the opposite. Their unique desert powers and fighting abilities that have been cultivated from their time in the desert prove to the audience that the Fremen are a mighty group of people who are simply suffering from the greed of others. Throughout the movie, they are depicted as a "good" group of rebels determined to tear down their oppressor. However, it is important to note, the movie sets up Paul Atreides, the white protagonist, to lead and save them. He is supposedly the "chosen one," called "Lisan al Gaib" by the Fremen which translates to prophet or messiah. Paul is meant to lead the Fremen to liberation from his own people—a very stereotypical white

savior narrative. In this way, it is plausible that the Fremen are depicted as weak and in need of saving by a white hero.

Another character of minoritized racial/ethnic identity present in the film is Dr. Yueh; the only Asian in the film whose character plays into a plethora of Asian stereotypes. He is seemingly a “kung fu” apothecary doctor with no developed storyline, and the only major part he plays in the plot is his betrayal to Paul’s father, which ultimately gets him and many others killed. Due to this orientalist portrayal of Dr. Yueh, many harmful Asian stereotypes are exaggerated and insinuated throughout the film.

*Mission Impossible - Fallout* (2018) has major limitations when it comes to a diverse cast of characters, with the only two characters of color being Erica Sloane and Luther. While there were no problematic portrayals identified for Sloane’s character with relation to Alvarado’s Theory of Ethnicity and Race, Luther’s character is seen to be in major need of saving at the start of the film, catalyzing all the events for *Mission Impossible - Fallout*. In a mission gone wrong, Luther is at gunpoint and Hunt must choose between letting the bad guys get away with the powerful, catastrophic plutonium cores or saving his friend. He ends up saving Luther and then must spend the rest of the film trying to retrieve what he lost. Thus, Luther is seen to be responsible for all the threats in *Mission Impossible - Fallout*. Though this specific situation paints him as a victim that needs saving from the white protagonist, it also aligns with the film’s plot as Luther is one of Hunt’s closest companions.

### **Analysis of Intersectionality in Film**

All films were also assessed for gender and racial bias from an intersectional lens. The Ko test was used to measure representation of women of color. A film would be awarded a pass score if all of the following indicators were observed: (1) There is a non-white, female character (2) who speaks in 5 or more scenes (3) and speaks English. The Waithe test was used to measure representation of black women. A pass score would be awarded if all of the following indicators were observed: (1) There is a black woman (2) who is in a position of power (3) and is in a healthy relationship with her partner. The Villalobos test was used to measure the representation of Latina women. A film would be awarded a pass score if all of the following indicators were observed: (1) The film has a Latina lead. (2) The lead or another Latina character is shown as professional or college educated, (3) speaks in unaccented English, (4) and is not sexualized.

*Interstellar* (2014) and *Inception* (2010) all failed the Ko test, as there were no women of color in either film. *Mission Impossible - Fallout* (2018) also failed, with only one woman of color (Erica Sloane) who does not speak in 5 or more scenes. *Dune* (2021), however, passed the test, as Liet-Kynes (a Fremen woman) speaks English in five or more scenes.

Similarly, all four films failed the Waithe Test. *Interstellar* (2014) and *Inception* (2010) had no Black characters. While the Fremen in *Dune* (2021) are a fictional race and made up of a variety of real-life ethnicities and cultures (including African and Middle Eastern), we identified Liet-Kynes (who is played by an identifiably black actress) as a Black character. She is in a position of power as the “Judge of Change,” however, she is not depicted to be in any

relationship. Thus, *Dune* (2021) also failed the Waithe test with only 2 out of the 3 criterias observed. *Mission Impossible - Fallout* (2018) also failed the test. While Erica Sloane is a female character of color in a position of power as a CIA director, she is not in any relationship known to the audience.

All films failed the Villalobos Test, as there were no Latina characters present.

## Discussion

Overall, the examination of the four most popular adventure movies from 2010-2023 from IMDB revealed that while women are often depicted as intelligent and essential to the film's plot, this identity is undermined by their hyper-emotional personality traits. Women also tend to be portrayed as "weaker" in comparison to their male counterparts. It was also determined that characters of color are frequently victimized on-screen, and both minorities were found to serve simply as motivation to enrich the lives of the white, male protagonists instead of developing their own unique stories. These conclusions largely support what was found in the literature reviews.

In *Interstellar* (2014), both Dr. Amelia Brand and Murph are written out to be highly intelligent characters but also extremely emotional. As previously noted, "Women are portrayed as dependent on other characters, overly emotional, and confined to low-status jobs when compared to enterprising and ambitious male characters" (Bussey and Bandura, 1999). This theme can also be seen in *Inception* (2010) with the character Ariadne. Despite her capabilities as an architect, her role as Cobb's "emotional" therapist is the identity that dominates her character throughout the film. Similarly, in *Dune* (2021), the powerful Lady Jessica dedicates her entire life to cultivate her son into a more powerful man. While all of these female characters are strong and intelligent, they are less developed; because they are only depicted enriching the lives of their male counterparts, they are seemingly less important than the male main characters. *Dune* (2021) specifically sees female characters associated with "themes of self-sacrifice, defined . . . .in relationship to children or to men, and have encouraged [the female audience] to identify with either female figures on screen who were powerless or victimized, or . . . with active male heroes" (Montgomery, 1984). Lady Jessica devotes her life to being a mother; the other prominent female character, Chani, is a part of a subjugated group of people. Even Liet-Kynes' death only occurs *after* she has done her part to help Paul Atreides escape. After she is found and stabbed by the Emperor's troops, she continues thumping her fist on the ground, knowing that it will attract the worm that will kill both the troops and herself. Thus, her death also plays into the common "self-sacrifice" theme as noted earlier.

Chani also isn't just motivation for Paul Atreides to fulfill his destiny, but the minimal screen time she has also tends to depict her in a seductive way: "A woman's physical attributes have traditionally received greater emphasis than her intellectual abilities. The importance to outer appearance has been underscored by the fact that often women have been shown to dress provocatively and belonging to a younger age category" (Basu, 2005). Paul's hazy, dream-like visions of Chani with wind in her hair, smiling at him, indicate a heavy emphasis on her

appearance more than anything else. She doesn't even have dialogue until the final scenes of the movie.

It's also important to note that all the other female characters including Murph and Dr. Brand from *Interstellar* (2014), Ariadne in *Inception* (2010), and Ilsa and Julia in *Mission Impossible - Fallout* (2018) are all slim and conventionally attractive women. Despite the fact that she is not East Asian, a connection can also be made between Paul and Chani as a "damsel in distress" and the prophesied white hero who has come to save her and her people. In this way, she is much like the meek China doll archetype who is often rescued by a white romantic love interest. An argument can also be made comparing Chani's character to the Dragon Lady archetype, as they are both portrayed as seductive and tough but eventually open up to and dominated by white love interests. We can also subtly see the China doll archetype at play in Julia's character in *Mission Impossible - Fallout* (2018) as the distressed damsel Hunt falls in love with. This goes to show how archetypes and themes noted for specific minority groups may also be applied to other races and ethnicities as well.

*Dune* (2021) also heavily plays on the white savior trope with the character Paul Atreides: "Across texts there are gradients of and variations on the white savior trope, but the overarching premise remains the same—a well intentioned white character intervenes and typically saves a lower-class, urban, non-white character from whatever fat that character would have encountered were it not for their lucky encounter with the film's white messiah" (Deutsch, 2020). While Deutsch specifically discusses white motherly figures in the presence of a black character's life, there can definitely be a connection between *Dune*'s (2021) white male protagonist, Paul Atreides, who is quite literally "the chosen one." While the first film ends with Paul meeting the Fremen for the first time, it is obvious that the film sets him up to be their "messiah," leading the Fremen to liberation from his own people. This paints the Fremen as a weak, victimized group of people in need of a white character to save them.

Another aspect of *Dune* (2021) that supports what was found in the literature reviews is its magical, desert-like setting. As noted earlier in the paper, "Arab countries are always presented as an unidentified mass of scorching deserts, and here the emphasis is on the wild, harsh, and uninhabitable terrain on which sporadic barbarian nomads roam, as only they can belong to such milieus" (Nashef, 2012). *Dune* (2021) only plays into this all too common setting for Middle Eastern inspired lands. With its boundless deserts and magical, blue-eyed and tan skinned native people who wield "desert power," it portrays the Fremen as an almost inhuman people. What worsens the situation is also the plethora of scenes depicting the Fremen as hooded characters chanting, once again "othering" the Fremen.

## **Recommendations**

As the portrayals of women and racial minorities continue to perpetuate problematic stereotypes, it is evident that change must be made on and off screen in order to foster more inclusive, diverse, and accurate depictions of these groups. One of the ways this may be achieved is to encourage and incentivise more women and racial/ethnic minorities to join the film industry



as producers, writers, directors, etc. According to a study which monitored the portrayal of women in top grossing films from 2002 to 2022, “films with at least one women director and/or writer were more likely than films with no women in these roles to feature higher percentages of females as protagonists, in major roles, and speaking characters” (Lauzen, 2022), while “films directed by white men tend to have less diverse casts than those directed by women and people of color” (Ramos, 2023). Though recruiting more people of color and women to the film industry does not necessarily guarantee more accurate portrayals of those groups on-screen, it is a step in the right direction. When diversity is absent behind the camera, it tends to be translated on-screen. This is a specifically urgent problem: “After trending upward for the past three years, racial, ethnic, and gender diversity among movie actors, directors and writers for theatrical releases slid back to 2019 levels, according to the new Hollywood Diversity Report” (Ramos, 2023). In order to improve on-screen representation, we must actively recruit and encourage minorities to take on roles behind the scenes.

Multiple states have already initiated efforts to diversify the film industry through film and TV tax credit. California, for example, requires the California Film Commission to submit annual diversity reports. They must also produce a diversity plan that reflects their demographics and must “make a good faith effort to meet their hiring goals” or 4% of the production’s tax credit will be deducted. From this initiative, data behind California’s employment data was released, which confirmed what many have already noticed: white people are overrepresented in Hollywood. Despite taking up 15% of the state’s population, only 7% of film and TV employees are Asian. Similarly, just 21% of the film industry’s workforce is Latinx, despite this racial group accounting for 40% of the state’s population. It is important that we aim to achieve a healthy balance and equal opportunity for all racial minorities behind the scenes. California’s film and TV tax credit system has yielded real results, demonstrating that diversity is achievable and some productions would actually hire a more diverse workforce. This legislation has already been spreading to other U.S. states such as New York, Illinois, and New Jersey.

The white, male-dominating space of the film industry can also largely be attributed to the racial and gender pay gap. Minorities face disproportionate financial barriers, which makes it more difficult for them to obtain jobs and get a proper education. Many lack the money and resources to study film, giving their richer, white, male counterparts a leg up. Hollywood, itself, has contributed greatly to the gender pay gap: “Even at the ‘superstar’ level, there is an estimated difference of over \$2.4 million between actors and actresses. With all potential outliers considered, there is still at least a \$1 million difference per film between the two genders. Data from 1980 to 2015 reveals an unexplained wage difference of 25% between male and female actors” (Park, 2022). It is no surprise that these statistics align with the lack of women and on-screen stereotypes we see in film. To alleviate this problem, adequate resources such as scholarships, internship opportunities, and training programs should be provided for women and individuals from racial/ethnic minority groups to study and gain practical skills in film. Additionally, pay equity analysis and audits should be conducted in the film industry, equitable

compensation policies should be developed, and remedies to adjust pay gaps and maintain pay equity should be prioritized.

Another potential solution to explore is providing diversity, equity, and inclusion (DEI) training for screenwriters. DEI programs are being implemented in diverse workplaces. Screenwriters play a major part in how female and minority characters are portrayed on-screen. Thus, it is important that they have cultural awareness and use diversity practices to create more inclusive and representative content. DEI initiatives have grown in popularity since 2020, with multiple film organizations using it as a framework to re-assess their own diversity and inclusion. In December of 2022, the TV Academy (which holds the Emmy awards) held a DEI summit as part of the Academy's 2021 diversity plan. After the 2015 #OscarsSoWhite campaign, which trended after people of color were entirely excluded from the nomination, the Academy Awards have also begun to turn to DEI initiatives. The Academy also established quotas for films in consideration for Best Picture.

However, there are concerns about this approach: "these quotas represent a broad and sweeping sea-change for the better from an industry perspective; however, this newly minted set of criteria has the potential to disqualify works of creative merit based on numerical qualifiers." To evaluate such a content-heavy, qualitative piece of work based on quantitative benchmarks is difficult. Perhaps a film meets these quotas, but the way they portray gender and racial/ethnic minorities is stereotypical, hyper-traditional, and harmful. It is also possible that a film may not meet the quota; however, this does not necessarily mean the film includes inaccurate or negative portrayals of diverse groups. A better, more comprehensive way to foster more inclusive and accurate portrayals of minorities is to focus on the messages their characters portray on-screen. This can be done by engaging with the people and communities being represented in the film. On-set consultations and in-depth screen reviews allow films to be more inclusive, authentic, and accurate.

## **Conclusion**

Since the birth of television, race and gender depictions on the small screen have drastically changed. It is clear that bigotry less often takes the form of blatant stereotypes, crude remarks, or racist jokes. Rather, sexism and racism have been embedded into the nooks and crannies of television, often hidden behind a diverse cast. As we continue to watch and analyze TV, we have to remember that not all representation is accurate and equitable representation, and what separates equitable and accurate representation from inequitable and stereotypical representation is nuanced and may be difficult to determine. American adventure film has consistently ignored and underrepresented women and racial/ethnic minorities, turning towards a more masculine cast and hyper-traditional portrayals. Even when minorities are represented, their characters tend to be underdeveloped and less important in comparison to their white male counterparts. A greater emphasis on accurate and inclusive portrayals in American film is necessary considering the lack of nuanced representations of women and racial/ethnic minorities in this study.

## Works Cited

- Basu, Aru. *Realm of Possibilities: The Portrayal of Women in Futuristic Science Fiction Movies*. 2005. Rochester Institute of Technology, MS thesis. scholarworks.rit.edu/cgi/viewcontent.cgi?article=8761&context=theses.
- Bussey, Kay, and Albert Bandura. "Social Cognitive Theory of Gender Development and Differentiation." *Psychological Review*, vol. 206, no. 1, 1999, pp. 676-713, psycnet.apa.org/doiLanding?doi=10.1037%2F0033-295X.106.4.676.
- Deutsch, Gabrielle. *Hardly Heartwarming: Constructing and Depicting Womanhood and the White Savior Trope in Contemporary Film*. 2020. Georgetown University, MA thesis. Georgetown Repository Library, repository.library.georgetown.edu/handle/10822/1059473.
- Lauzen, Martha M., Dr. *It's a Man's (Celluloid) World, Even in a Pandemic Year: Portrayals of Female Characters in the Top U.S. Films of 2021*. San Diego State University, 2022, womenintvfilm.sdsu.edu/wp-content/uploads/2022/03/2021-Its-a-Mans-Celluloid-World-Report.pdf.
- Lee, Joey. "East Asian 'China Doll' or 'Dragon Lady'?" *Bridges: An Undergraduate Journal of Contemporary Connections*, vol. 3, no. 1, 2018, scholars.wlu.ca/cgi/viewcontent.cgi?article=1026&context=bridges\_contemporary\_connections.
- Means Coleman, Robin R., and Emily Chivers Yochim. *The Symbolic Annihilation of Race: A Review of the "Blackness" Literature*. African American Research Perspectives, 2008, deepblue.lib.umich.edu/handle/2027.42/60140.
- Montgomery, Sarah. "Women's Women's Film." *Feminist Review*, 1984, sec. 18, pp. 38-48.
- "Most Popular Movie Genres in the United States and Canada between 1995 to 2023, by Total Box Office Revenue." *Statista*, 16 May 2023, www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjzoP6k5LyBAxXWk4kEHZmoBK0QFnoECBYQAQ&url=https%3A%2F%2Fwww.statista.com%2Fstatistics%2F188658%2Fmovie-genres-in-north-america-by-box-office-revenue-since-1995%2F&usg=AOvVaw1Sw\_M3HX3sfO3iVgtWxYp1&opi=89978449. Accessed 21 Sept. 2023.
- Murphy, Jocelyn Nichole. *The Role of Women in Film: Supporting the Men -- an Analysis of How Culture Influences the Changing Discourse on Gender Representations in Film*. 2015. University of Arkansas, MA thesis. ScholarWorks@UARK, scholarworks.uark.edu/jouruht/2/.
- Nashef, Hania A.M. *Barbaric Space: Portrayal of Arab Lands in Hollywood Films*. 2012, hcommons.org/deposits/item/mla:657/.
- Park, Joann. "Uncovering Hollywood's Contribution to the Gender Pay Gap." *Berkeley Political Review*, 12 Oct. 2022, bpr.berkeley.edu/2022/10/12/uncovering-hollywoods-contribution-to-the-gender-pay-gap/

- Ramón, Ana-Christina, Dr., et al. *Hollywood Diversity Report 2023*. 2023, [socialsciences.ucla.edu/wp-content/uploads/2023/03/UCLA-Hollywood-Diversity-Report-2023-Film-3-30-2023.pdf](https://socialsciences.ucla.edu/wp-content/uploads/2023/03/UCLA-Hollywood-Diversity-Report-2023-Film-3-30-2023.pdf).
- Ramos, Barbra. "Diversity Takes a Step Back in Theatrical Films – but Strides Forward in Streaming." *UCLA Newsroom*, 30 Mar. 2023, [newsroom.ucla.edu/releases/hollywood-diversity-report-spring-2023-movie-industry](https://newsroom.ucla.edu/releases/hollywood-diversity-report-spring-2023-movie-industry). Accessed 16 Sept. 2023.
- Sheen, Robert. "DEI & the Academy Awards: New Film Industry Guidelines Address Diversity & Inclusion." 8 Oct. 2020, [trusaic.com/blog/dei-the-academy-awards-new-film-industry-guidelines-address-diversity-inclusion/](https://trusaic.com/blog/dei-the-academy-awards-new-film-industry-guidelines-address-diversity-inclusion/).
- Smith, Stacy L., Dr., et al. *Inequality in 1,600 Popular Films: Examining Portrayals of Gender, Race/Ethnicity, LGBTQ+ & Disability from 2007 to 2022*. University of Southern California, Aug. 2023, [assets.uscannenberg.org/docs/aii-inequality-in-1600-popular-films-20230811.pdf](https://assets.uscannenberg.org/docs/aii-inequality-in-1600-popular-films-20230811.pdf).

## **Richard Nixon: The Man Who Out-McCarthyed Joseph McCarthy By Oliver Meyer**

### **“When You Go Out to Shoot Rats. . .”: Introduction**

On 13 March 1954, then Vice-President Richard Milhous Nixon delivered a consequential, yet mostly forgotten, speech. Republican Wisconsin Senator Joseph McCarthy, notorious for his anti-communist agenda and personal attacks, had angered Republican Party leadership during the Army-McCarthy hearings held by the United States Senate’s Subcommittee on Investigations by accusing the United States military of communist infiltration (Government Publishing Office). President Eisenhower delegated Nixon to respond. In his meticulously crafted address, the vice-president stated that “When you go out to shoot rats...[if] you shoot wildly it not only means that the rat may get away more easily, you make it easier on the rat... Men have...made themselves the issue rather than the cause they believe in so deeply. And when they’ve done this...they have diverted attention from the danger of communism” (Nixon 86). Nixon achieved Eisenhower’s goals: distancing the administration from McCarthy – albeit without mentioning him by name – while ensuring the American people that the fight against communist influence in the United States continued.

Following the end of World War II in 1945, Republican politicians had intensified criticism of the progressivism inspired by Roosevelt’s policies in the 1930s (Greenberg 22). Their opposition targeted New Deal regulations and overly powerful labor unions, and now melded with another emerging Republican Party concept: anti-communism (Greenberg 23). As such, opposition to the New Deal was used to push anti-communism to the center of Republican Party politics. At the same time, the beginning of the Cold War in 1947 inspired increased anti-communist actions, such as President Truman’s March 21 Loyalty Order designed to purge any communist influence from the U.S. government. Richard Nixon, an aspiring politician at the outset of the Cold War, capitalized on the anti-communism agenda, relying on it in his political rise.

To understand why an anti-communist platform could propel someone to political victories at both state and national levels, we must appreciate the broad political spectrum in the post-WWII United States. While the end of the war and the start of the Cold War ushered in a substantial rise in conservative popularity, the Communist Party USA (CPUSA) also gained traction. And at the beginning of 1947, party membership peaked at over 75,000 people (Gregory Washington.edu). While minute compared to mainstream political movements, the CPUSA’s rise allowed Republican politicians to run campaigns and base political careers upon an anti-communist platform. Richard Nixon did just that.

Nixon capitalized on dissolving relations between the U.S. and its former ally, the U.S.S.R., and he ascended from the House of Representatives in 1946 to the presidency in 1968, in large part due to his anti-communist rhetoric and actions (Nixonfoundation.org). His crucial implementations of the anti-communist platform occurred in his 1946 House campaign, his actions as a congressman, and his 1950 Senate campaign (Nixonfoundation.org).

But if Nixon implemented a similar platform to that of Senator McCarthy, how did he avoid McCarthy's fate-- namely condemnation from his own party and a congressional censure? This question has remained largely unexplored by historians (Mason 27; Greenberg 19). It is, however, important, because the answer demonstrates that Richard Nixon understood that a successful political rise required constant shifts in tone and behavior. While equally rabid in his anti-communist views, Nixon avoided McCarthy's fate because he recognized when to soften his rhetoric to remain within evolving Republican Party bounds. Furthermore, Nixon's willingness to sacrifice those in his party who stepped out of line appeased party leadership. In the end, Nixon subdued Joseph McCarthy, someone with whom he shared political beliefs. Analyzing various political calculations by both Nixon and McCarthy throughout their careers highlights Nixon's ability, and McCarthy's inability, to shift both rhetoric and tone, and to present appropriate facts, when required.

Perhaps the reason this aspect of his career is overlooked is because when discussing Nixon's legacy, many Americans focus not on the ways in which he acquired and remained in power, but rather on his role in the June 17, 1972 Watergate scandal, in which five people broke into the Democratic National Committee Headquarters, and his subsequent attempts to deny knowledge of the incident (Alice History.com). His spectacular demise eclipsed his rapid but less dramatic rise. Unsurprisingly, historical works, such as Stanley Kutler's 1990 *The Wars of Watergate* and Garrett Graff's 2022 *Watergate: A New History*, dwell mainly on Nixon's Watergate scandal while president, and only briefly mention the events that catalyzed his rise (Graff 33; Kutler 153).

Nonetheless, some historians have accepted the idea that Nixon's weaponization of the anti-communist platform played an important role in his political rise. In a 1993 article, Michael Riccards explained that Nixon's first congressional race, along with his later national campaigns revolved around a "demagogic use of anti-communism" (Riccards 740). His rise within Republican politics, Riccards argued, was due less to conservative philosophy than his "virulent" anti-communism. Historian John Earl Haynes agreed. In 2003, he explained that anti-communism was a position rather than a movement, because the term described groups and ideas people rejected rather than supported (Haynes 1; Schrecker 29). Furthermore, Haynes described multiple types of anti-communism, only one of which was political (Haynes 1). Republicans utilized this form to attack their Democratic foes in an attempt to link them and their support of New Deal policies to communism to diminish their popularity (Haynes 1). Though these historians agreed upon how Nixon initially rose to national prominence, most neglected to explain his continued rise in national politics. In his 2005 *Americans at War*, historian John Malsberger noticed that throughout Nixon's political career, he shifted from confrontational anti-communism to negotiable, less absolute anti-communism (Malsberger 4). What Malsberger missed, however, was how this change represented a broader pattern in Nixon's behavior: strategically toning down his rhetoric as Republican Party boundaries narrowed. Historian Marta Rzepecka proved an exception to this pattern of misapprehension of Nixon's political acumen. In her journal article, she explored how Nixon's evolving rhetoric, a

topic integral to the authentic Richard Nixon story, served to further his political career (Rzepecka journals.theasa.net).

Everyday Americans shared similar accounts of the traditional narrative of Nixon. In four interviews conducted for this work, two with Nixon loyalists and two with staunch Nixon critics, all interviewees, who were around the age of thirty during the scandal, remembered Nixon primarily for his role in Watergate (B. Meyer; A. Meyer; L. Friedland; M. Friedland). This essay maintains that Nixon's weaponization of the anti-communist platform guided him through his steady political climb from poor boy in Yorba Linda, to the presidency of the United States of America. His meticulous, timely, and successful executions of the anti-communist platform also allowed him to avoid the negative fate of Senator Joseph McCarthy, when Republican Party strategy departed from severe anti-communism (Trenton Evening Times). Nixon's developing rhetoric, persistent anti-communism, and willingness to follow party orders allowed for his rise, and highlighted the importance of continued party support throughout a politician's ascent. His flexible strategy represented the norm in post-WWII Republican politics, therefore illuminating a successful implementation of the Republican Party blueprint of the time.

“Of Course, I Knew That Jerry Voorhis Wasn't A Communist.”: 1946 Congressional Race Following nearly four years in the United States Navy, thirty-three year old Lieutenant Commander Richard Nixon was honorably discharged from active duty on March 10, 1946 (History.navy.mil). Why would the lieutenant and rising military star want to leave his post (History.navy.mil)? Because Richard Nixon had political aspirations, and had already agreed to stand for election.

As the 1946 election cycle neared, both the Los Angeles County Republican Central Committee, led by John S. Barcome, and the twelfth Congressional District Republican Committee, chaired by Roy Day, strove to find a suitable candidate for the race (Bullock 321). With the war's objectives completed, some feared that communism would spread through the world just as Nazism had in years prior (Greenberg 11). Therefore, as Day explained, “We must win in 1946 and...preserve a Constitutional form of government...free from bureaucratic control” (Greenberg 11). Once again, opposition to both New Deal policies and communism was undoubtedly interconnected. Conservative politicians oftentimes compared New Deal programs to those of Soviet communism. Day and Barcome launched a candidate-and-fact-finding committee, and press releases were printed in multiple Republican newspapers (Greenberg 12). Importantly, the releases stated that the one-hundred-person committee hoped for a young congressional candidate with no prior political experience and preferably one who had served in the military (Greenberg 12). Opting for someone with no political experience offered a glimpse into the Republican Party strategy, as a new politician could call for change in Washington, DC, having never been a part of the political machine. Furthermore, a veteran could describe accounts of communism both domestically and abroad. In September 1945, Herman Perry, a Bank of America local branch manager, submitted Nixon's name for consideration (Greenberg 12). As committee member McIntyre Faries explained, Nixon was noticed as a “good speaker and a man of promise (Greenberg 12). Perry then wrote to Nixon, who grew excited at the prospect of

running for office. Nixon flew home to Whittier to interview for the role in November 1945. And while the committee originally selected Dr. Walter Dexter as their preferred candidate, he died in October 1945 (Bullock 322). Next, the committee tagged General George S. Patton, Jr. as another possible candidate. He died on December 21, 1945, the day that Lieutenant Commander Richard Nixon publicly accepted the committee's endorsement (Bullock 322).

While Nixon's Republican primary competition was nominal, the general election proved more daunting. Beyond Whittier, Nixon was relatively unknown, and the incumbent, Democrat Jerry Voorhis, a popular congressman with a lauded record, had served as a representative since the 1936 Democratic FDR landslide (Bullock 323). Two questions emerged: was the twelfth congressional district, a Democrat stronghold, an obtainable seat for a Republican? And how would Nixon pursue it?

Following WWII, veterans returning to California struggled to find homes, and wartime amalgamation among world powers, especially between the U.S. and U.S.S.R. gradually descended into suspicion and distrust (Bullock 321). Richard Nixon, a lawyer and veteran, capitalized on these issues. Conservative enough to attract his Republican base but also politically savvy enough to sway Independents and Democrats, Nixon emerged as an ideal candidate (Bullock 323).

With a number of key issues open for exploitation, Nixon made his selection: anti-communism. His decision represented a larger shift in Republican Party politics post-WWII. In what would become a signature strategy of his political rhetoric shared with Senator McCarthy, Nixon turned to Red-Baiting, an extreme version of anti-communism, in which he attempted to discredit an opponent by linking him to communism in any form whatsoever (Snccdigital.org).

Two months before the general election on November 5, 1946, Nixon first publicly linked Voorhis to the Congress of Industrial Organizations Political Action Committee, (CIO-PAC) which he claimed was influenced by communists (Bullock 328). The first ever PAC in the United States, the CIO-PAC was formed in 1944 by the Congress of Industrial Organizations and its left-wing, though anti-communist leader, Sidney Hillman (Greenberg 23). Contrary to Nixon's accusations, Voorhis was not endorsed by the CIO-PAC. During his kickoff speech in La Puente on July 26, 1946, however, Nixon declared that "I have no personal criticism of my opponent as a man, and I do not believe that personalities should be inserted into the campaign." Immediately following, he personally attacked Voorhis, alleging that he was endorsed by the PAC and was allied with radical left-wing groups (Bullock 329).

In September, 1946, while delivering a speech in Pomona, Nixon once again referenced the CIO-PAC, arguing that "Today the American people are faced with the choice between two philosophies of government. One of these, supported by the radical PAC and its adherents, would deprive the people of liberty through regimentation" (Bullock 340). Nixon used his campaign speeches to great effect, scaring voters into believing Voorhis had formidable communist ties. In reality, actual communists disavowed liberal politicians like Voorhis, who focused on what communists labeled anti-Russian hysteria (Bullock 329). Nixon's rhetoric resonated with many



voters, who believed that he would help save the country from the perceived threat of communist influence and infiltration. As local Whittier attorney Wallace Black argued, “It was good politics.... I would describe it as a pretty hard-fought campaign by a young, up-and-coming political leader” (Greenberg 23).

In addition to campaign speeches, Nixon effectively weaponized the candidate debates as a platform to attack his opponent (Gellman 70). The first and most notable of these occurred on September 14 in the auditorium of a South Pasadena high school. Voorhis, tired of Nixon’s false personal attacks in regard to communist influence, was finally prepared to call Nixon’s bluff and demand proof that he was endorsed by the CIO-PAC (Bullock 337). During the question and answer portion of the debate, Voorhis got his wish when a Democrat in the audience asked Nixon why he was falsely claiming that Voorhis had CIO-PAC support (Greenberg 24). In a dramatic scene, Nixon responded by strolling across the stage and shoving a piece of paper towards Voorhis (Bullock 337). Before the debate, a political committee of the Southern California chapter of the National Citizens' PAC (NCPAC) had supported an endorsement of Voorhis. The piece of paper presented by Nixon contained that recommendation (Bullock 337). To underscore the gravity of this discovery, Nixon listed the names of people who worked for both the CIO-PAC and the NCPAC, arguing that “It’s the same thing, virtually, when they have the same [subversive] directors” (Greenberg 24). Doing so made the NCPAC indistinguishable from the CIO-PAC, the one which Nixon originally accused of endorsing Voorhis. This sleight of hand was typical of Nixon’s political strategies.

Such theatrics flustered Voorhis, who lost much of the audience's support. As Nixon supporter Lyle Otterman recalled, Nixon “proceeded to take Voorhis apart piece by piece, and tossed him around the audience” (Greenberg 23). Otterman considered the debate decisive for Nixon, who was in the minority when he began his speech (Greenberg 25). As the night unfolded, Otterman could “pick up around me the feeling that this guy’s [Nixon] not so bad after all” (Greenberg 25).

Following the debate, the press and the Voorhis camp alike recognized the debate’s damage. As the Los Angeles Times described, “Voorhis was at particular pains to clear himself of any implications that he was pro-Russian” (Greenberg 25). When Voorhis asked Chester Hollifield, a Democratic congressman from Southern California and a campaign advisor, about his debate performance, Hollifield quipped: “Jerry, he murdered you. He used every dirty trick in the book” (Gellman 70).

Nixon’s dirty tricks did not stop on the debate stage. Only a few days before the election, constituents in the twelfth district received calls that stated, “Did you know that Jerry Voorhis was a communist” (Bullock 350)? On election day, in a race that was meant to have solidified the twelfth district’s solid Democratic influence, Richard Nixon defeated incumbent Jerry Voorhis by seven percentage points and more than fifteen thousand votes (Bullock 356). His victory signaled a larger shift in California and national politics. The 1946 election marked the first time Republicans had won control of Congress since 1928 (Daniel 79). In California alone, Republican candidates flipped seven Democratic-held districts (House.gov). All seven

Republican incumbents also won their races, resulting in fourteen Republican representatives from California, to the Democrat's nine (House.gov).

Ten years after his 1946 House victory, Nixon was quoted by one of his biographers as claiming that "communism was not the issue at any time in the '46 campaign. Few people knew about communism then, and even fewer cared" (Costello 53). If Nixon was sincere in this belief, it is clear that he had set his sights on higher political office rather than simply remaining a representative from California (Westad 127). He understood that anti-communism would grow into both a California state as well as a national issue, and he counted on that fact to catapult himself to the national stage.

Nixon himself strengthened this view. In a post-election conversation with former Jerry Voorhis assistant Stanley Long, Long rebuked Nixon's campaign tactics, especially concerning the communist issue (Bullock 354). In response, Nixon tellingly remarked, "Of course, I knew that Jerry Voorhis wasn't a communist" (Bullock 354). The anti-communist platform provided Nixon an unlikely victory, which encouraged him to continue its use. While candidate Nixon employed anti-communist rhetoric to propel himself to the House, it remained to be seen how he would navigate the issue as Congressman Nixon.

### III

#### "Spy Hunter": Nixon's Years In The House Of Representatives, 1946-1950

Congressman Nixon was prepared to bring anti-communism to the forefront of his congressional career. Both the two principal causes with which he was associated during his four years in the House – The Mundt-Nixon Bill and the Alger Hiss case – were associated with anti-communist work (Costello 182). His committee assignment on the House Committee On Un-American Activities (HUAC) on February 13, 1947, gave him the platform to emerge as one of the more vocal members in the anti-communist community (Gellman 107).

For a freshman congressman who devoted the majority of his 1946 campaign to anti-communism, a position on HUAC seemed desirable. Yet Nixon, wary of HUAC's tenebrous past, did not lobby for the assignment. Originally created in 1938 by Democratic Congressman Samuel Dickstein – a supposedly staunch anti-communist who actually spied for the Soviet Union – to investigate Nazi subversion prior to WWII, HUAC quickly widened its investigatory scope to include the detection of communists (Gellman 107). Democrats selected Martin Dies, a Democratic congressman from Texas, as chair of the committee, and he spearheaded efforts to expand the powers of HUAC, including the use of vigilante tactics to intimidate, and sometimes punish, witnesses (Gellman 108). For example, when HUAC investigated alleged Communist Party sway in Hollywood in 1947 and 1951, the hearings resulted in the blacklisting or firing of approximately three hundred actors and others in the movie industry (Schultz mtsu.edu). Many subpoenaed by HUAC invoked their fifth amendment right and therefore did not testify. The committee perceived such a decision as equivalent to an admission of guilt, and many such individuals were cited for contempt of Congress. Given Nixon's harsh campaign tactics, it is fair to question why he was skeptical of a position on the committee which employed techniques

similar to those of his own campaign. Was he sincere in his skepticism, or was it merely a face-saving ruse?

Five days after his committee assignment, Nixon delivered his maiden speech to the House of Representatives on February 18, 1947 (Tanenhaus Theatlantic.com). In it, he highlighted the dangers of communist infiltration of the United States government, recounting the story of Gerbert Eisler, a communist agent who traveled between Moscow and the United States (Nixon Watergate.info). And in a unifying message, Nixon defiantly stated that "It is essential as members of this House that we defend vigilantly the fundamental rights of freedom of speech and freedom of the press... [but these rights] do not carry with them the right to advocate the destruction of the very government which protects [those] freedom[s]." His message signaled two important elements of his time in the House. He would continue to focus on communist subversion, but discontinue the personal anti-communist attacks of his political campaigns. Throughout his career, a pattern emerged: highly competitive election campaign Nixon differed greatly from highly effective politician Nixon.

A further shift in Nixon's attitude occurred when the new congressman discussed his committee assignment on January 14, 1947. He claimed that HUAC should "ferret out un-American activities of government employees to the end that extremists of both the left and the right, whether they be communist or fascists, shall be removed from the federal payroll" (Gellman 107). This rhetoric, which was reasonably appealing to citizens of most political persuasions, was a far cry from his exclusively anti-communist 1946 campaign rhetoric. Nixon was clearly attempting to broaden his personal appeal.

Another question emerged. Would this more measured tone extend to the work he conducted on HUAC? The answer was yes, and his newfound attitude, which was perceived as intensely sincere, was a hallmark of his personality (Costello 183). Similar to many successful politicians, Nixon's rhetoric shifted following his progression from candidate to congressman.

Nixon transformed HUAC into a functioning legislative body (Costello 187). And while members of congress could always propose legislation, committee members used their newfound power to both investigate communist subversion and author specific anti-communist legislation in their capacity as HUAC members. In late 1947, Nixon was appointed chairman of the special legislative subcommittee, and after conducting hearings in February 1948, he assembled two monographs on communist operational tactics, and authored a report which sketched a fresh offensive on the Red Conspiracy (Costello 187). Soon thereafter, the Mundt-Nixon bill (House Resolution 5852), named for its authors Nixon and South Dakota congressman Karl Mundt, was introduced (Costello 187).

The main components of the bill targeted the activity of CPUSA members: mandatory registration with the Attorney General, and denial of passports and federal employment opportunities (Costello 187). Even with ample anti-communist legislation already in effect, the bill was sent out of committee unanimously (Costello 187). Three days of debate on the House floor ensued, beginning on May 14, 1948, and the Congressional Record on that day revealed that Nixon once again stood out for his courteous treatment of the opposition, led by communist

sympathizing New York congressman Vito Marcantonio (Costello 188). Notably, during the debate, Nixon granted Marcantonio additional time when the New York congressman's ninety minutes had expired (Costello 188). Furthermore, Nixon understood each component of the bill, oftentimes answering the opposition's precise questions (Congress.gov). When Democratic Colorado congressman John Carroll probed Nixon on whether a provision in the bill would hinder the Attorney General's right to proscribe under the president's executive order, Nixon concisely and effectively calmed Carroll's concerns (Congress.gov). He explained that for the Attorney General to deem an organization as a communist front, he would be required to follow specific procedures, which were subject to court review (Congress.gov). Congressman Carroll, satisfied with Nixon's clarification, interjected to "thank the gentleman [Nixon] very much" (Congress.gov).

Not only was Nixon's debate performance impressive, but so was the timing of the proposed bill. With anti-communism now synonymous with successful Republican Party strategy, Nixon and Mundt purposely introduced their bill during an election year (Costello 187). Republican politicians who had seen the positive effects of the anti-communist campaign approach would certainly vote in favor of the bill. Even many Democrats, who did not want to appear as soft on communism, voted for the bill in the House. Democratic Georgia Congressman John Stephens Woods, for example, lauded the bill, arguing that those who observed the growth of communist philosophy abroad were "more and more concerned with its spread in this country" (Congress.gov). Stephens continued, specifically praising Nixon and HUAC's legislative subcommittee, which Nixon chaired, for working "tirelessly for weeks upon weeks to aid the author in perfecting this piece of legislation" (Congress.gov). And in a House with 246 Republicans and 188 Democrats, the bipartisan bill passed by a vote of three hundred and nineteen to fifty-eight (Encyclopedia.com).

Such a glowing review of the bill was not shared absolutely, and the Mundt-Nixon bill fizzled in the Senate, largely due to Republican opposition to the 'un-American' bill. Thomas Dewey, a former Republican New York governor, argued that "stripped to its naked essential, this [Mundt-Nixon bill] is nothing but the method of Hitler and Stalin. It is thought-control borrowed from the Japanese" (Costello 189). Newspapers throughout the country echoed Dewey's sentiment, with the New York Times warning that the bill could "be used to impose restraints on freedom such as the American people have not known" (Costello 189). Both the Denver Post and the St. Louis Post-Dispatch agreed with the New York Times' assessment (Costello 189; NYTimes.com). On March 9, 1950, even the Republican San Francisco Chronicle concluded that the Mundt-Nixon bill was "completely backhanded and totally subversive of the spirit and letter of the Constitution" (Costello 190). While this opposition was enough to kill the bill in the Senate, a similar one which included many of Nixon's principal ideas passed not long after, once again propelling Nixon into the national spotlight (Costello 190).

Nixon's anti-communist work extended beyond legislation. In fact, it was his role in the Alger Hiss affair that proved to be the climax of his congressional career (Costello 191). On August 3, 1948, Whittaker Chambers, a former Communist Party member, was summoned by

HUAC to corroborate the testimony of a defected Soviet spy, Elizabeth Bentley, who accused multiple government officials of communist affiliation (Alger Fbi.gov). Alger Hiss, a former Justice Department official, was one of those named by both Bentley and Chambers (Alger Fbi.gov). Hiss vehemently denied the claims, and given the fact that Chambers provided no proof that Hiss committed espionage, the case could have concluded (B. Andrews and P. Andrews 29). But Nixon, not satisfied with Chambers' testimony to the committee, continued the investigation, forcing Chambers to disclose information which demonstrated that there was more to his story (Alger Fbi.gov). In November 1948, Nixon's persistence paid off: Chambers provided documents proving that both he and Hiss committed espionage (Alger Fbi.gov). In early December, Chambers submitted more irrefutable evidence: materials hidden inside of a pumpkin – The Pumpkin Papers – including pictures of state department materials and handwritten notes from Alger Hiss (Alger Fbi.gov; Chambers New York). Nixon's indefatigable pursuit of legitimate subversive activities in conjunction with a leak of case details to the press catapulted both him and the Alger Hiss affair to national prominence: his name was plastered on newspapers nationally from August to December, 1948.

In its December 8 edition, The Kansas City Star featured an article on the congressman, discussing how Nixon's "hunt was on" for three people accused of handing over United States documents to a Russian official (ProQuest Kansas City Times). The Idaho Statesman followed a similar pattern, referring to Nixon as a "spy hunter" in its December 23 edition (Idaho Statesman). Equally important, the article painted Nixon as a fair congressman, only interested in truly subversive activities (Idaho Statesman). In fact, it was Nixon who sought answers from the Federal Bureau of Investigation (FBI) after Laurence Duggan, a formal State Department Official, mysteriously plunged to his death following FBI questioning into Duggan's alleged subversive activities (Idaho Statesman). Whittaker Chambers testified that Duggan was not a communist operative, and Nixon argued that this testimony "cleared" Duggan's name (Idaho Statesman). The Trenton Evening Times also highlighted Nixon's desire to adopt new rules ensuring greater rights to witnesses under committee suspicion. In fact, it was Democratic Mississippi congressman John Rankin who led the opposition to these proposals by Nixon and his colleagues, arguing that such rights would serve to hinder the committee's abilities. Overall, Richard Nixon's work in the House represented a considerable adjustment from his congressional race just a few years prior. After his vicious 1946 campaign, in which Nixon attacked his opponent's character and questioned his loyalty to the United States, Nixon spent his four years in congress conducting successful anti-communist work, even gaining a reputation for his fair treatment of the opposition. With his sights set on higher political office, however, Nixon announced his run for the Senate in the 1950 election, and during his effort, campaigner Nixon reverted to personal, and frequently false attacks on his opponent.

"Tricky Dick": 1950 Senate Race And Moving Up The Political Chain

With a favorable anti-communist record in the House, Nixon centered his 1950 Senate campaign on those successes, highlighting the Alger Hiss affair and his role in it (Costello 197; Wikimedia.org). Arguing that "[t]he Hiss case exposed the blindness of the Truman

Administration and its predecessors to the problem of communist subversion in government” (Nixon Law2.umkc.edu). Nixon attempted to link the guilt of one individual to the Democratic Party as a whole (Costello 200). Alleging guilt by association exposed Nixon’s dual personality: hero as legislator and villain as campaigner.

In his attempts to link those in the Democratic Party to communism, Nixon deviated from campaigning on his record and focused on delegitimizing his opponent, Congresswoman Helen Gahagan Douglas (Bird 37). The desire to further his own political career was continuously at the forefront of his mind, even if it included personal and baseless attacks. Nixon was not unique in employing such practices. As former ABC chief White House correspondent Sam Donaldson noted when describing American politics, “anything works, if it works. Nevermind whether it is ethical...fair...[or] factual. If it works for you, do it” (Youtube.com FiveThirtyEight 13:28) In this Senate race Nixon earned his nickname – Tricky Dick – for his attempts to link Douglas to communism using his infamous Pink Sheets. These campaign fliers stressed the votes by Congresswoman Douglas which the Nixon team believed would upset California voters. For example, the Pink Sheets displayed the three hundred and fifty-four times Douglas voted with alleged Communist Party liner and Bronx congressman, Vito Marcantonio. Ironically, Richard Nixon himself voted with Marcantonio over two hundred times, indicating that this tactic was both misleading and factually insufficient to prove communist sympathies.

Similar to his 1946 House race, Nixon’s disingenuous campaign proved successful, and in a state that had last sent a Republican to the Senate in 1926, Richard Nixon won his 1950 race by around six hundred thousand votes, and nearly twenty percentage points (House.gov). Nixon had again won an unlikely victory using an anti-communist platform, along with his selective presentation of facts.

Whereas Nixon’s 1946 House victory represented a larger Republican shift in California, his 1950 contest demonstrated that California voters continued to trust Republican politicians. Republicans won thirteen of the twenty-three congressional races, gaining one seat from 1948. As mentioned, though, Nixon was the first Republican senator elected in California in over thirty years, indicating his important role in this newfound Republican Party success. Though Congressman Nixon’s work in the House of Representatives was executed in an attempt to uncover actual subversive activities, both his 1946 congressional and 1950 Senate campaigns were deceitful; he manipulated data and constructed evidence in an attempt to link his opponents to communism, counting on strong anti-communist sentiment. Even Nixon recognized just how brutal his campaign tactics were. In a 1957 interview with then Vice-President Nixon, British publisher David Astor asked him to explain his 1950 campaign, especially in relation to his personal attacks against Helen Douglas. Nixon reportedly looked up from his desk and stated “I’m sorry about that episode. I was a very young man” (Costello 74).

His questionable tactics notwithstanding, Nixon was rewarded by Republican Party leadership generally, and presidential candidate Dwight D. Eisenhower specifically, only a few years later, indicating the direction of Republican Party politics: win at all costs. Two years into his first term as a senator, the Republican nominee for the presidency in 1952, Dwight David

Eisenhower, selected Richard Nixon as his choice for vice-president (Koscielski 19). Nixon, who grew famous both for his ability to label opponents as subversive and his popular and productive work in the House, was a solid selection for Eisenhower. Furthermore, Nixon was willing to do the administration's unpleasant tasks, even if it forced him to banish those in his own party (Koscielski 19).

Eisenhower's selection proved successful, and in the 1952 presidential election, Nixon helped the campaign earn California's thirty-two electoral votes. The election marked the first time since 1928 that California had voted for a Republican presidential candidate. "We've Got To Be Fair...It's The Most Effective Way Of Doing The Job.": Nixon's Ability To Remain In Power

While Richard Nixon's rise largely depended upon his anti-communist tendencies in rhetoric and action, one major question remained: How did he avoid the negative fate of his ideological colleague Senator Joseph McCarthy, who similarly relied on anti-communism to foster a political rise? The answer was simple. Nixon recognized when the extreme version of anti-communism, Red-Baiting, was necessary, and also when a more measured, moderate message was appropriate. As such, Nixon made clear shifts in his rhetoric and action from the campaign trail to office. Nixon was the greater politician.

On the campaign trail in both his 1946 House and 1950 Senate races, Nixon barked personal attacks at his opponents – Jerry Voorhis and Helen Douglas – in an attempt to link them personally, and the Democratic Party generally, to communism (Bullock 359). While a congressman from 1946 to 1950, however, Nixon departed from Red-Baiting in favor of conducting investigations into and uncovering true communist subversion. Furthermore, Nixon appeased party leadership with his willingness to put the Republican Party ahead of personal convictions, even if that meant denouncing those with whom he shared a political philosophy. In other words, he was a good soldier. Best described by prominent member of the Democratic Socialists of America Irving Howe, Nixon was "a well-oiled drawbridge between McCarthyite barbarism and Eisenhower respectability." Vice-President Nixon, at President Eisenhower's behest, delivered his When You Go Out to Shoot Rats speech, which castigated Senator McCarthy after having overstepped Republican Party bounds. In the speech, Nixon argued that while exposing communists and communist sympathizers was paramount, "[w]e've got to be fair...it's the most effective way of doing the job." As a member of congress only a few years before, Nixon consistently treated his opposition, communist or not, in the same respectful manner with which he treated political allies (Costello 186). As previously discussed, in the Mundt-Nixon bill debate, he allotted additional time to the opposition led by an alleged communist sympathizer (Costello 186).

Unlike Nixon, Joseph McCarthy's Red-Baiting knew no limits. He even went so far as to accuse the U.S. military, an institution that Republicans overwhelmingly supported, of communist subversion. Doing so highlighted McCarthy's focus on sensational personal convictions rather than Republican Party politics, which in turn jeopardized his career. A few months after Nixon's March speech, and around a month after McCarthy's army hearings in

which he accused the military of communist infiltration, Republican Senator Ralph Flanders of Vermont introduced a resolution aiming to censure Senator Joseph McCarthy on July 30, 1954 (Senate.gov). After months of debate, on December second, 1954, a bi-partisan Senate voted sixty-seven to twenty-two to censure McCarthy (Senate.gov). While ostensibly for his failure to cooperate

with and his abuse of the Subcommittee on Privileges and Elections, the real issue was McCarthy's communism accusations against Brigadier General Ralph W. Zwicker during the army hearings which forced many Republicans to shun him (Senate.gov). During the 2nd December debate on the Senate floor, Republican Michigan senator Charles E. Potter condemned McCarthy, arguing that "no greater insult can be hurled at a military man...than to say...that he is unfit to wear the uniform of his country...If I had been in uniform and such a statement had been made to me, my reaction would have been much more violent than was that of General Zwicker" (Congressional Record).

"I Must Put The Interest Of America First": Conclusion

In 1945, then Lieutenant Commander Richard Nixon set his sights on a political career. By all objective measures, he succeeded, winning House elections in 1946 and 1948, a Senate election in 1950, Vice Presidential elections in 1952 and 1956, and Presidential elections in 1968 and 1972. His only national loss occurred in the 1960 Presidential election, won by John F. Kennedy. His formidable ability to shift his rhetoric was displayed again in his 1968 presidential campaign, only a few years after what many believed to be the end of his political career. His desire for ever-increasing political power propelled him from congressman at thirty-four to vice president at forty and president at fifty-six years old. That same desire would ultimately result in a downfall more rapid than his rise.

In the leadup to the 1972 presidential election, Nixon appeared set on course for victory. Yet he succumbed to temptation, indirectly participating in the June 17, 1972, Watergate scandal. He had no need for such illicit tactics, evidenced by the fact that he won five hundred twenty out of the five hundred thirty-eight electoral votes in the 1972 election (National Archives). His participation in the scandal, subsequent denial of it, and the results of an investigation that followed, led him to resign from the Office of the Presidency on August 9, 1974. In his resignation speech the night before, Nixon stated that "I have never been a quitter. To leave office before my term is completed is abhorrent to every instinct in my body. But as President, I must put the interest of America first. America needs a full-time President... Therefore, I shall resign the Presidency effective at noon tomorrow" (Nixon Pbs.org).

During his rise, two distinct Nixons emerged. On the campaign trail, the combative Nixon delegitimized his opponents by attempting to link them to communism. In the process, he earned his nickname, Tricky Dick. As a presidential candidate in 1968, however, Nixon strayed away from the anti-communist platform, even advocating for increased negotiation with the Soviet Union (Rzepecka journals.theasa.net). His recognition that the American people had lost interest in his anti-communist tactics, and his decision to focus on other issues, highlighted his willingness to shift rhetoric, one of his great strengths as a politician. He could read the crowd.



As an elected official, the productive Nixon exposed true communist subversion, highlighted by his work on the Alger Hiss case in 1948 (Hamilton 29). By carefully crafting his strategies and willingly remaining within Republican Party bounds, Nixon solidified continued party support and his rise through the political ranks.

Nixon's story also raises a particular question. What happens when a politician who has much ambition reaches the highest office in the nation? After ascending to the presidency in 1968, there was nowhere for Nixon to go. Is it possible that his Watergate scandal – the single event for which he is most remembered – was predictable based on his insatiable hunger for more political power and control?

As President Richard Milhous Nixon remarked in his resignation address, “For more than a quarter of a century in public life I have shared in the turbulent history of this era” (Nixon Pbs.org). He most certainly did.

## Works Cited

- Alger Hiss. *Fbi.gov*. 2023. Retrieved from <https://www.fbi.gov/history/famous-cases/alger-hiss>.
- Andrews, Bert, and Peter Andrews. *A Tragedy of History*. Robert B. Luce, 1962.
- Bird, Michael. *The Pink Lady and Tricky Dick: Communism's Role in the 1950 Senatorial Election*. *Eiu.edu*. Retrieved from <https://www.eiu.edu/historia/Bird2014.pdf>.
- Bullock, Paul. 'Rabbits and Radicals' Richard Nixon's 1946 Campaign against Jerry Voorhis. *Southern California Quarterly* 55. 3 (1973): 319-359. Retrieved from <https://doi.org/10.2307/41170489>.
- Chambers, Whittaker. *Witness*. New York: Random House, 1987.
- Congressional Record-Senate. *Congress.gov*. 1954. Retrieved from <https://www.congress.gov/bound-congressional-record/1954/12/02/senate-section>.
- Costello, William. *The Facts about Nixon: The Unauthorized Biography of Richard M. Nixon, The Formative Years 1913-1959*. New York: Viking Press, 1960.
- Daniel Farber. "'Mere Shadows': The Early Cold War." In *Security V. Liberty: Conflicts Between National Security and Civil Liberties in American History*, 67-94. New York: Russell Sage Foundation, 2008.
- Encyclopedia.com. "Refuting the Mundt-Nixon Bill." *Encyclopedia.com*. Oxford University Press. Retrieved from <https://www.encyclopedia.com/politics/news-wires-white-papers-and-books/refuting-mundt-nixon-bill>.
- Friedland, Larry. Interview by the author. New York. March 20, 2023.
- Friedland, Marilyn. Interview by the author. New York. March 20, 2023.
- Gellman, Irwin F. *The Contender: Richard Nixon, the Congress Years, 1946-1952*. New Haven: Yale University Press, 2017.
- Government Publishing Office. "McCarthy and Army-McCarthy Hearings." *Senate.gov*. Retrieved from <https://www.senate.gov/about/powers-procedures/investigations/mccarthy-and-army-mccarthy-hearings.htm>.
- Graff, Garrett M. *Watergate: A New History*. New York: Simon & Schuster, 2002.
- Greenberg, David. *Nixon's Shadow: The History of an Image*. New York: W. W. Norton & Company, 2003.
- Gregory, James. "Communist Party Membership by Districts 1922-1950." *Departments.Washington.Edu*. Retrieved from [https://depts.washington.edu/moves/CP\\_map-members.shtml](https://depts.washington.edu/moves/CP_map-members.shtml).
- Hamilton, Neil A. "Nixon, Richard." In *Richard Nixon. Facts On File*, 2018. Retrieved from [online.infobase.com/Auth/Index?aid=15322&itemid=WE52&articleId=166103](https://online.infobase.com/Auth/Index?aid=15322&itemid=WE52&articleId=166103).
- Haynes, John Earl. "Anticommunism." In *Dictionary of American History*, 3rd ed., edited by Stanley I. Kutler, 197-99.1. New York: Charles Scribner's Sons, 2003. Retrieved from [https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3401800211/UHIC?u=nysl\\_me\\_horman&sid=bookmark-UHIC&xid=c05416cc](https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3401800211/UHIC?u=nysl_me_horman&sid=bookmark-UHIC&xid=c05416cc).

- History.navy.mil "Commander Richard M. Nixon, USNR." Naval History and Heritage Command. Retrieved from <https://www.history.navy.mil/browse-by-topic/people/presidents/Nixon.html#:~:text=In%20January%201942%2C%20Nixon%20became,Reserve%20on%2015%20June%20194.>
- Idaho Statesman. "Mundt Wants Reason G-Men Called Duggan." Boise. December 23, 1948. Retrieved from [https://infoweb-newsbank-com.horacemann.idm.oclc.org/apps/news/document-view?p=EANX-K12&t=&sort=YMD\\_date%3AD&page=4&fld-nav-0=YMD\\_date&val-nav-0=1948%20-%201948&fld-base-0=alltext&maxresults=20&timeline\\_search=true&val-base-0=Richard%20Nixon&docref=image/v2%3A114CF38DF1A90B10%40EANX-K12-14F7F793F739D34B%402432909-14F65674406E65F6%400-14F65674406E65F6%40.](https://infoweb-newsbank-com.horacemann.idm.oclc.org/apps/news/document-view?p=EANX-K12&t=&sort=YMD_date%3AD&page=4&fld-nav-0=YMD_date&val-nav-0=1948%20-%201948&fld-base-0=alltext&maxresults=20&timeline_search=true&val-base-0=Richard%20Nixon&docref=image/v2%3A114CF38DF1A90B10%40EANX-K12-14F7F793F739D34B%402432909-14F65674406E65F6%400-14F65674406E65F6%40.)
- Koscielski, Frank. "Nixon's Impact: Did Richard M. Nixon's Intense Anti-Communism Serve the National Interest?" In *History in Dispute*, edited by Robbie Lieberman, 223-27.19. Detroit: St. James Press, 2005. Retrieved from [https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX2877900040/GVRL?u=nysl\\_me\\_horman&sid=bookmark-GVRL&xid=64a57fc9.](https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX2877900040/GVRL?u=nysl_me_horman&sid=bookmark-GVRL&xid=64a57fc9.)
- Kutler, Stanley I. *The Wars of Watergate: The Last Crisis of Richard Nixon*. New York: W. W. Norton & Company, 1990.
- Library of Congress. "Congressional-Record-House." *Congress.gov*. Retrieved from <https://www.congress.gov/bound-congressional-record/1948/05/14/house-section.>
- Malsberger, John W. "Nixon, Richard M." In *Americans at War*, edited by John P. Resch, 143-44.4. Detroit: Macmillan Reference USA, 2005. Retrieved from [https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3427300404/UHIC?u=nysl\\_me\\_horman&sid=bookmark-UHIC&xid=b1af5643.](https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3427300404/UHIC?u=nysl_me_horman&sid=bookmark-UHIC&xid=b1af5643.)
- Mason, Robert. *Richard Nixon and the Quest for a New Majority*. Chapel Hill: University of North Carolina Press, 2004. Retrieved from <https://ebookcentral.proquest.com/lib/horacemann/reader.action?docID=413351&query=Richard+Nixon.>
- Meyer, Arthur. Telephone interview by the author. New York. March 21, 2023.
- Meyer, Barbara. Telephone interview by the author. New York. March 21, 2023.
- Meyer, Gerald. *Vito Marcantonio: Radical Politician 1902-1954 (SUNY Series in American Labor History)*. New York: State University of New York Press, 1989.
- National Archives. "1972 Electoral College Results." *Archives.gov*. Retrieved from <https://www.archives.gov/electoral-college/1972.>
- Nixon Richard. *Six Crises*. New York: Simon & Schuster, 1962. <http://law2.umkc.edu/faculty/projects/ftrials/hiss/nixononhisscase.html>.
- Nixon, Richard M. "President Nixon's Resignation Speech." *Pbs.org*. Retrieved from [https://www.pbs.org/newshour/spc/character/links/nixon\\_speech.html.](https://www.pbs.org/newshour/spc/character/links/nixon_speech.html.)

- Nixon, Richard Milhous. "When You Go out to Shoot Rats." In *Richard Nixon : Speeches, Writings, Documents*, edited by Rick Perlstein, 84-87. Princeton: Princeton University Press, 2008. Digital file.
- Nixon, Richard. "Congressman Nixon's Maiden Speech to the House of Representatives." Speech presented in Washington DC, February 18, 1947. Watergate.info. Retrieved from <https://watergate.info/1947/02/18/nixon-maiden-speech-to-house-of-representatives.html>.
- Nixonfoundation.org. "Richard Nixon Timeline." Nixonfoundation.org. Retrieved from <https://www.nixonfoundation.org/resources/richard-nixon-timeline/>.
- NYTimes.com. New York Times Company. "Newscaster Tells of Order to 'Slant.'" Archives.nytimes.com. Last modified March 15, 1950. Retrieved from <https://archive.nytimes.com/www.nytimes.com/books/98/02/01/home/nixon-slant.html>.
- Online.infobase.com. *The Richard Nixon Vice Presidency: Research without the Nixon Manuscripts*. In *A Companion to Richard M. Nixon*. Hoboken: Wiley-Blackwell, 2011. Retrieved from <http://online.infobase.com/Auth/Index?aid=15322&itemid=WE52&articleId=369651>.
- Popovici, Alice. "Watergate: Who Did What and Where Are They Now?" History.com. Last modified June 15, 2012. Retrieved from <https://www.history.com/news/watergate-where-are-they-now>.
- ProQuest. *The Kansas City Times (Kansas City)*. "At Odds on Number of Suspected Spies." December 8, 1948. ProQuest Historical Newspapers.
- Riccards, Michael P. "Richard Nixon and the American Political Tradition." *Presidential Studies Quarterly* 23.4 (Fall 1993): 739-45. Retrieved from <https://www.jstor.org/stable/27551150>.
- Rzepecka, Marta. "Richard Nixon's Campaign Rhetoric of Anti-Communism." *Polish Journal for American Studies*, 49-61.6 Retrieved from [https://journals.theasa.net/images/contributor\\_uploads/PJAS\\_vol6\\_05Rzepecka.pdf](https://journals.theasa.net/images/contributor_uploads/PJAS_vol6_05Rzepecka.pdf).
- Schrecker, Ellen. "McCarthyism." In *Dictionary of American History*, 3rd ed., edited by Stanley I. Kutler, 181-83.5. New York: Charles Scribner's Sons, 2003. Retrieved from [https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3401802469/UHIC?u=nysl\\_me\\_horman&sid=bookmark-UHIC&xid=099c606b](https://link-gale-com.horacemann.idm.oclc.org/apps/doc/CX3401802469/UHIC?u=nysl_me_horman&sid=bookmark-UHIC&xid=099c606b).
- Schrecker, Ellen. "McCarthyism: Political Repression and the Fear of Communism." *Social Research* 71.4 (2004): 1041-86. Retrieved from <http://www.jstor.org.horacemann.idm.oclc.org/stable/40971992>.
- Schultz, David. "House Un-American Activities Committee." Mtsu.edu. Retrieved from <https://www.mtsu.edu/first-amendment/article/815/house-un-american-activities-committee>.
- Senate.gov. *The Censure Case of Joseph McCarthy of Wisconsin (1954)*. Senate.gov. Retrieved from [https://www.senate.gov/artandhistory/history/common/censure\\_cases/133Joseph\\_McCart](https://www.senate.gov/artandhistory/history/common/censure_cases/133Joseph_McCart)



## **Genetic Testing Decision Making: A Game Theoretic Model By Anirudh Kumar**

### **Abstract**

Genetic diseases affect around 200,000 people in the United States (Cleveland Clinic, 2021). These are the result of mutations passed down through families leaving a history of disease by inheritance. Several genetic testing kits have become popular in recent years, and have led to positive outcomes for those affected by specific conditions which can be identified and treated before becoming more problematic later in life (e.g. BRCA). However, the decision about whether or not to take a test is not always clear-cut due to financial and psychological implications. For this reason, I have created a model that aids in the decision-making process for someone considering a genetic test. My analysis assumes that patients start with an initial belief about harboring a genetic mutation based on their family history of the disease. As patients receive results for genetic tests, this belief changes. Besides the initial belief, the two other inputs into this analysis are test accuracies and insurance thresholds<sup>1</sup>. At each given test accuracy and insurance threshold, some patients will opt to take the genetic test, and some will not, depending on their initial beliefs. There is a breakpoint<sup>2</sup> in initial beliefs in which the optimal choice switches from not taking the test to taking the test. As tests become more accurate, patients will become more confident in future health problems arising and more willing to pay for preventive procedures regardless of whether their health insurance will reimburse the costs. These dynamics are captured in the model discussed below.

### **Introduction**

Human diseases arise from two primary sources: pathogens and genetics. Genetic diseases account for over one third of human diseases, and generally result from mutations in DNA (Vendette, 2019). The human body contains DNA, the molecule that codes for proteins to be produced. These proteins can perform various functions, which includes preventing hereditary diseases from developing. A mutation in DNA can prevent these preventive proteins from being produced, and therefore result in the disease developing. Since children inherit much of their DNA from their parents, existing mutations in a parent's DNA may be passed on to a child, making them more likely to develop a disease. The inheritable nature of these diseases instills a sense of dread in many inheritors, who are left unsure of whether they may develop the disease or pass the mutation on to their children. In recent years, scientists have developed methods to detect the presence of specific mutations in a person's DNA. Such methods can help patients know how to plan their lives better or undergo preventive treatment to minimize the chances that they develop a disease. However, taking a genetic test may not always be the most rational decision, depending on a variety of factors.

The cost of genetic tests vary, and many patients may not be willing or able to pay the price. Insurance companies don't always financially support the patient in undergoing preventive treatment after discovering mutations from a genetic test (although financial support is more common if the probability of the mutation existing is high enough). (Medline Plus, 2021; Kliff,

2023) If a test comes back positive (the test indicates the presence of a mutation in the patient's DNA), a patient may be incentivized to undergo preventative measures (e.g., breast removal for breast cancer). These treatments can be costly, and insurers are hesitant to cover the costs of procedures if the genetic test's results don't indicate a particular DNA mutation is present. A patient's financial standing plays a major role in their decision-making process. Poorer patients will be sacrificing more of their scarce resources to undergo genetic testing or associated preventive procedures. This paper aims to find a path for patients to know whether taking a genetic test is an optimal or suboptimal choice considering patients' varying circumstances.

### **Project Overview**

The decision-making model described below is meant to analyze a patient's expected payoffs while factoring in their family history and financial conditions. Considering these variables, a patient can use this model to make optimal decisions.

The model first considers the most crucial decision: whether the patient should take the genetic test at all. The patient's decision depends on how much the insurance will be willing to support the cost of the genetic test. Next, the patient must decide whether they want to undergo preventative treatment based on the outcome of the genetic test *and* the probability that they may have a particular mutation. Using the terminology of game theory (See Game Theory section), all "players" (patients) start the "game" (series of decisions) with an initial "belief" (confidence) that they have a mutation responsible for developing a disease and that "belief" will change based on the outcome of the test(s). After the patient takes a genetic test, their "belief" that they have the mutation is updated. An insurance company may only support a patient if the insurance company's "belief" that the patient has the mutation is above a certain threshold. As such, the patient must consider whether the insurance company will support the patient's treatment or not. In addition, if a patient is still not confident that the updated "belief" is accurate, they may choose to retake the test. This can cause the "belief" to increase or decrease, potentially moving above or below the threshold. If a patient engages in multiple genetic tests, the patient can become more certain in their decision making. However, taking genetic tests is not free, and the more times the patient takes a genetic test, the more money the patient will spend, thereby diminishing the total "payoff" the final result will bring.

I found that as the test accuracy increases, patients are more likely to take the test given their new beliefs are higher and the insurance will be more likely to support them. For accurate tests, the threshold<sup>1</sup> the insurance companies set does not change the breakpoint<sup>2</sup>. However, the insurance threshold becomes more prevalent as test accuracy decreases. With less accurate tests, a higher insurance threshold means a higher breakpoint, so fewer people are likely to take a genetic test. For example, if a test has a 90% accuracy, then there is no difference between a 60% insurance threshold and a 90% insurance threshold. However, for a 70% test accuracy, a 90% threshold increases the breakpoint by 3%, meaning fewer people will take the genetic test. To maximize the number of tests taken by people at risk, insurance companies, and any other

policymakers, ought to lower the threshold at which they support treatment to incentivize more testing.

### **Game Theory**

Game Theory is the study of how players should approach a situation to come to the optimal solution. This solution can maximize benefits for each player assuming they behave rationally. These games can occur over one step (all players make a single decision and assess the outcome) or multiple steps (both players make a series of decisions). A situation occurring over multiple steps (also called a multi-stage game) can be modeled by a 'game tree.' 'Game Trees' can show how a situation progresses; different people should make decisions based on the benefits that they might receive. At the end of each decision-making process, players receive what is called a payoff. Players will always want to maximize their payoff by the end of a game.

A multi-stage game is analyzed by starting from the end. Each outcome of the game tree is examined, and based on the chance that each outcome occurs, one can discover the average payoff of making certain decisions. By doing this, the optimal decision for each stage of the game can be found by working backwards until finding the set of decisions with the highest payoff. This process is referred to as backward induction. When this process is applied to genetic testing, payoffs are calculated based on what the patient currently knows about how likely it is they have the disease-causing mutation (their current belief).

Every time a patient takes a test, the patient's perceived probability that they have the disease-causing mutation updates. This updated belief is referred to as the posterior. The posterior can be calculated by multiplying the probability of a certain event and the prior belief and dividing that by the probability of the event. For instance, when looking at how the patient's belief changed after a positive test, consider their initial belief in the possibility they had the disease, and the accuracy of the test. The product of multiplying the patient's initial belief and the test accuracy gives the probability that the patient 1) has the mutation and 2) the test comes back positive. This is then divided by the probability that any positive result will return. This can be calculated by, again, multiplying the initial belief that the patient has the mutation and the probability the test was correct (true positive), and adding it to the initial belief that the patient did not have the mutation and the probability the test was incorrect (false positive). Every time an average payoff for a decision is calculated, it is done so based on what the patient currently thinks is the probability they have the mutation and considering that their payoff they undergo preventative treatment.

### **Health Insurance**

The patient is not the only person involved in the decision-making. When a patient takes a genetic test, or undergoes preventative treatment, any health insurance the patient may have will be involved in the situation. Regardless of the type of insurance, the health insurance company has a vested interest in supporting the patient, but ideally wants to pay as little as possible to maximize profits. Health insurance companies can support their clients in two ways:

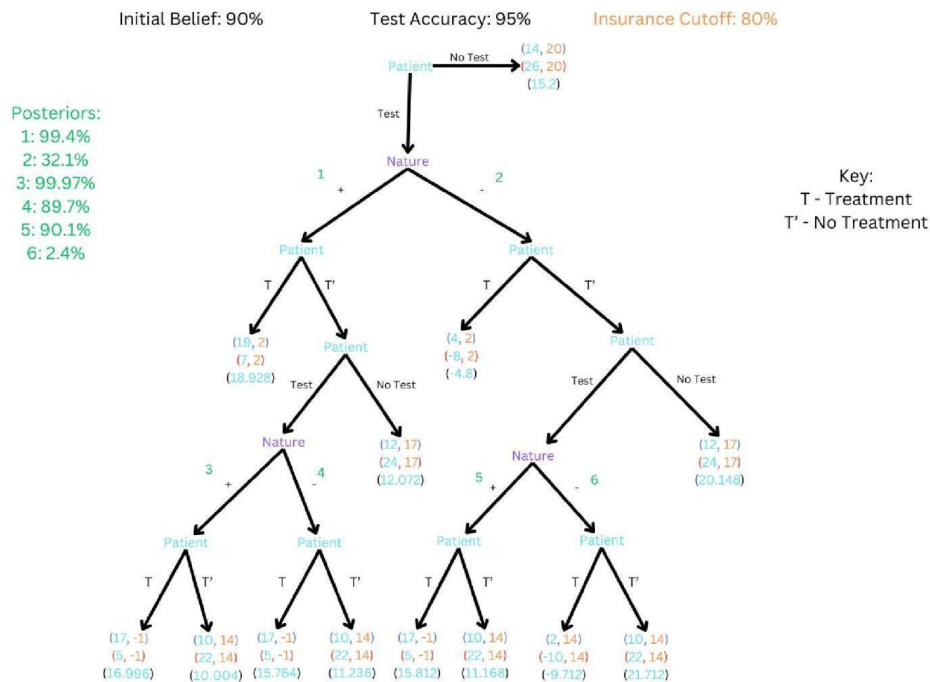


through copayments or deductibles. Copayments involve the patient and health insurance company paying a certain percentage of the total cost, while deductibles involve the patient paying a portion of the with the health insurance company covering the rest of the cost.

Theoretically, a genetic test result should not affect chances of insurance coverage or reimbursement. The Genetic Information Nondiscrimination Act (GINA) was passed in 2008 to prevent health insurance from raising rates or dropping coverage based on genetic test results. (U.S. Equal Employment Opportunity Commission, 2008) This law, however, is not always significant, as health insurance companies can still choose to not financially support a patient if they provide a logical reason for not doing so. Reasons may include believing there are safer, cheaper, less invasive, and more effective alternatives and/or believing that such treatments are unnecessary (Patient Advocate Foundation, 2020). A genetic test result may lead to the belief that the mutation is present in the patient (the posterior) extremely low, causing the insurance to drop coverage for tests and treatments. For this analysis, I have assumed the insurance will have a threshold for when they will support a patient and when they will not.

### Game Tree

The game tree (See below figure for an example) is the model that displays the entire decision-making process for the patient and health insurance company.



The Game Tree Model shows the different payoffs for the patient and the insurance company. Any payoffs in blue parentheses are the payoffs if the patient does have the mutation, and the payoffs in red parentheses are the payoffs if they do not have the mutation. Since there is no way of knowing for sure whether the patient has the disease or not, the average payoff for

each branch is calculated, based on the latest posterior (in green). The patient's average payoff for each branch is written in black parentheses.

When considering the game tree, the patient has a choice to ignore taking a genetic test and undergoing treatments completely. This can be the case in the event the patient is not initially certain that they have the mutation. Choosing this will end the game immediately, as I have assumed insurance companies would seldom financially support a patient who has not taken at least one genetic test. Patients who are both well off financially and are sufficiently certain they have the mutation, however, can choose this option and pay for the entire treatment themselves without guarantees of reimbursement from health insurance. If the patient decides to take the first test, then the result will return positive or negative. These different possibilities are modeled by another 'player' called "nature". Nature represents an extraneous 'player' who does not receive payoffs but displays decisions outside of other players' control. Based on the result of the test (positive or negative) a different posterior is calculated, changing the belief on whether the patient has the mutation and whether the insurance would financially support them. After this, the patient can choose to undergo preventative treatment (with or without insurance support). If they choose not to undergo treatment, the game will repeat. The patient can now decide to take a second test if they are unsure of the first test's result. If the patient does not take the second test, the game ends and payoffs are calculated. If the patient takes a second test, a new posterior is calculated using the belief after the first test. From this, the patient can again decide whether to undergo preventative treatment based on if the insurance will support them. When considering the payoffs for the two players (the patient and the insurance), both players are given a starting value of '20'. This can realistically be any number; 20 is just an arbitrary value. People of lower economic status may start with a lower number. With each genetic test, the patient and insurance payoffs will decrease by a certain amount (in this case 2 and 3 respectively) to represent the cost of the genetic test. Genetic tests vary in cost, so the payoffs may need to be altered depending on the cost of the genetic test and the amount a patient must pay for it. The preventative treatments also have a cost and decrease the players' payoffs significantly. In this model, for the preventative treatment, the patient's payoff decreases by 5 if the insurance supports them, and 20 if the insurance does not. The insurance's payoff decreases by 15 if they support the patient, and 0 if they do not. Alongside decreasing the payoffs based on tests and treatments, the payoffs for the patient also change if they make the correct decision. If the patient's decision aligns with the potential result, then their payoff increases by 6. If not, it decreases by 6. This 6 is again an arbitrary value that can be changed. For each outcome, there are two potential payoffs, one in which the patient has the mutation, and one where they do not. For example, if a patient elects to undergo preventative treatment and they have the mutation, then that payoff increases by 6. If a patient chooses to undergo the treatment and does not have the mutation, then their payoff decreases by 6. The two payoffs for that particular outcome (one payoff where they have the mutation, one where they do not) are then averaged based on the probability that the patient believes they have the mutation. This probability comes from the latest posterior or belief.

An alternative method to modeling the payoffs for outcomes is using “Certainties”. “Certainties” are increases or decreases in payoffs if the posteriors exceed a certain amount. For instance, if the posterior is between 80% and 90%, the patient choosing to take the treatment might have a payoff increase of 4, since they are quite certain they have the mutation, and the treatment is worth it. A patient choosing not to take the treatment, however, might have a payoff decrease of 4, since the chance they have the mutation is high and not taking the treatment might have consequences later. Whether the model is done with certainties or averages, however, does not entirely matter, since both models reach the same set of decisions.

### Parameter Changes

The game trees involve three variable parameters, an initial belief (the probability everyone thinks the patient has the disease in the beginning), the accuracy of the tests a patient takes, and the threshold the insurance has chosen. Based on the accuracy of the test there is a certain point where the patient’s initial belief will change their choice (the breakpoint). For instance, as shown in Table 1 (using the aforementioned arbitrary values), any patients who initially believe there is a 37% chance or lower that they have the mutation will not take a test with a 95% accuracy. Any patients with an initial belief of 38% or higher will take the test. As the test accuracy increases, the cutoff for when the patient decides to take the test decreases. As is shown in Table 1, the most reasonable thresholds for when an insurance company supports a patient (60% to 90%) do not change the point where the patient’s decision changes. The insurance threshold has become more important for tests with lower accuracies.

**Table 1**  
*Breakpoints for Accurate Tests and Insurance Cutoffs*

		Test Accuracy			
		95%	97%	99%	99.9%
Insurance Cutoff	60%	38%	34%	33%	30%
	70%	38%	34%	33%	30%
	80%	38%	34%	33%	30%
	90%	38%	34%	33%	30%

In this table, the rows show the breakpoints where a patient chooses to take the test for different insurance thresholds. The columns show the breakpoints where a patient chooses to take the test for different test accuracies.

Posteriors decrease as test accuracy decreases, and the insurance company’s threshold then holds more weight. If a patient whose initial belief was around 70% took a test with 70% accuracy (shown in Table 2), then the posterior after a positive test result would be between 80% and 90%. As such, if the insurance has a threshold of 80% or lower then treatment after the first test would usually be supported. If the threshold is at 90%, however, then the treatment after the

first test would not be supported. In this case, the insurance's threshold is more important to consider as the breakpoint changes from 72% to 75%.

**Table 2**

*Breakpoints for a Less Accurate Test and Insurance Cutoffs*

		<b>Test Accuracy</b>
		<b>70%</b>
<b>Insurance Cutoff</b>	<b>60%</b>	72%
	<b>70%</b>	72%
	<b>80%</b>	72%
	<b>90%</b>	75%

In this table, a test is done with a much lower accuracy than normal, that of 70%. In this table, the only insurance threshold to alter the breakpoints is the one of 90%. A 90% insurance threshold increases the point where the patient's decision changes from not taking the test to taking the test.

An increase in the breakpoint indicates that fewer people are taking the genetic test. This can be detrimental as this means people with relatively high initial beliefs that are below 75% are not taking the test. While the difference between 72 and 75 is not a lot, as the test accuracy decreases the insurance's threshold will become more influential, increasing the breakpoint differences. As such, as the test accuracy decreases, it is advised that the insurance threshold also decreases to support more people with relatively high initial beliefs.

**Factors Outside Insurance**

The matter of taking a genetic test is not always about money. Certain diseases like Huntington's Disease do not have any notable cures or treatments. Taking a genetic test for these types of diseases only provides information on whether the patient may develop the disease or pass it on to their children, helping them prepare for potential life decisions. This information can be very beneficial regardless, however there can also be harmful consequences.

When a patient takes a genetic test, there will almost always be a psychological impact on the patient. If a test comes back positive, then any dread they may have had towards developing the disease may increase, which can negatively impact their lives. Outside of the patient themselves, a positive test result can also affect their family. Family members may experience depression and other negative symptoms due to the knowledge that someone close to them may be living for a limited time. Alongside this, the results of a genetic test also reveal information on family members. For example, a positive test result indicates a sibling or cousin of the patient could also have the mutation.

The knowledge that someone may be a mutation carrier can also be very damaging. Patients may be torn over whether to have a child, and test results can impact their lives for years. False test results, especially, have been noted to have harmful effects on people. From an article from the Genomics Institute at UC Santa Cruz, Katy Mathes and her sister underwent

genetic testing in August of 2015 and received results that they were likely to develop breast or ovarian cancer later in their lives. Since their family had a history of the disease, they considered the results seriously and underwent surgery alongside five other family members. Years later, information was received that the mutation variant that they had been diagnosed with had since been reclassified. Initially, the mutation had been identified as pathogenic, or capable of causing disease. When it was reclassified, however, the classification changed to ‘unknown’. (Genomics Institute, 2020) This is just one example of how a genetic test was proven unreliable and had significant consequences on not just one patient, but their entire family as well.

When considering a genetic test, it is not just a financial situation that should be considered. There is the type of disease, whether it is treatable, how will it affect family members, or is having a child important to the patient? Depending on the value a patient may place on factors outside their financial status, the payoffs they would receive for each outcome could increase or decrease, thereby changing their decision. When considering if someone should take a genetic test, it is important to personalize the game tree to reflect the values the patient places in outside factors.

## **Conclusion**

To summarize, this paper introduces a model that can help people understand whether they should take a genetic test. There are various tests for different hereditary diseases, and some are more accurate than others. Based on their family history, a patient will have an initial belief on how likely they are to inherit a disease-causing mutation and will have an insurance company that will support preventative treatment if the probability they have a disease reaches a certain threshold. Based on the insurance threshold and the test accuracy, the patient’s initial belief will dictate whether they should take the first test. If their initial belief reaches the breakpoint, they will take the test, and if their initial belief falls below the breakpoint, they will not take the test. It was found that with more accurate tests, the breakpoints where the patient’s decision changes decrease, so more patients take the test. At high test accuracies, the insurance threshold is mostly negligible. However, with lower test accuracies, a high insurance threshold will increase the breakpoint and fewer people will take the test. As such, insurance companies should lower their thresholds if the patient is taking a test with a low accuracy to ensure that more people are taking the genetic test when they have an appropriately high initial belief.

These models only display the patient’s financial payoffs and their relationship with their insurance. If a patient has any factors outside insurance that would change their decision, it is best to change the payoffs of the model to accommodate the patient’s circumstances.

## **Further Research**

This model can be further researched by understanding how the second test influences a patient’s decision. When a patient is deciding whether to take the second test, another breakpoint can be found on when the patient’s decision changes, based on the latest posterior and the initial belief.

Besides better understanding the second test, the model can also be changed to incorporate other players, such as the patient's family. A patient's family members may be just as affected by the results of a genetic test as the patient themselves, and they might also play a role in the patient's decision. The game tree can be improved to incorporate some of the patient's family based on their beliefs and what decisions they might make to influence the patient. This would help model what might happen in real life more accurately.

## Works Cited

- Ambry Genetics. "Variant Classification." *Ambry Genetics*,  
www.ambrygen.com/science/variant-classification#:~:text=Pathogenic%20Mutation,for%20pathogenic%20mutation%20carriers%20recommended. Accessed 7 Aug. 2023.
- American Porphyria Foundation. "DNA Testing for Porphyria." *American Porphyria Foundation*,  
porphyriafoundation.org/for-patients/about-porphyrin/testing-for-porphyrin/dna-testing-for-porphyrin#:~:text=If%20a%20mutation%20(or%20change,of%20known%20disease%20causing%20mutations. Accessed 7 Aug. 2023.
- Breastcancer.org . "Genetic Testing For Breast Cancer." *Genetic Testing Stories*,  
www.breastcancer.org/genetic-testing. Accessed 7 Aug. 2023.
- Brownlee, Jason. "A Gentle Introduction to Bayes Theorem for Machine Learning." *MachineLearningMastery.Com*, 4 Oct. 2019,  
machinelearningmastery.com/bayes-theorem-for-machine-learning#:~:text=This%20allows%20Bayes%20Theorem%20to,Posterior%20%3D%20Likelihood%20\*%20Prior%20%2F%20Evidence.
- Cleveland Clinic. "Genetic Disorders." Cleveland Clinic, 20 Aug. 2021,  
my.clevelandclinic.org/health/diseases/21751-genetic-disorders.
- Genomics Institute, UC Santa Cruz. "I Would Have Had Another Kid': How an Imperfect Gene Test Led to Major Surgery-and Big Regrets." *Genomics Institute*, 7 Jan. 2020,  
genomics.ucsc.edu/2020/01/09/i-would-have-had-another-kid-how-an-imperfect-gene-test-led-to-major-surgery-and-big-regrets/.
- Gianelli & Morris. "What to Do If My Insurance Denies Surgery Coverage." *Gianelli & Morris*, 10 May 2022,  
www.gmlawyers.com/insurance-denies-surgery-what-to-do#:~:text=Insurance%20companies%20deny%20procedures%20that,than%20a%20bad%20faith%20denial.
- Huntsman Cancer Institute, University of Utah Health. "Can I Afford Genetic Testing for Cancer Risk?" *Huntsman Cancer Institute | University of Utah Health*, 15 Oct. 2021,  
healthcare.utah.edu/huntsmancancerinstitute/news/2021/10/can-i-afford-genetic-testing-cancer-risk.
- Kliff, Sarah. "Health Plans No Longer Have to Cover All Preventive Care at No Cost. Here's What to Know." *The New York Times*, 31 Mar. 2023,  
www.nytimes.com/2023/03/31/health/obamacare-coverage-preventive-care-aca.html.
- Medline Plus . "What Is Genetic Discrimination?: Medlineplus Genetics." *MedlinePlus*, 28 July 2021, medlineplus.gov/genetics/understanding/testing/discrimination/. Accessed 7 Aug. 2023.
- Medline Plus. "What Are the Risks and Limitations of Genetic Testing?: Medlineplus Genetics." *MedlinePlus*,  
medlineplus.gov/genetics/understanding/testing/riskslimitations#:~:text=Genetic%20test

- ing%20can%20provide%20only,disorder%20will%20progress%20over%20time.  
Accessed 8 Aug. 2023.
- Medline Plus. “What Is the Cost of Genetic Testing, and How Long Does It Take to Get the Results?: Medlineplus Genetics.” *MedlinePlus*, medlineplus.gov/genetics/understanding/testing/costresults/. Accessed 7 Aug. 2023.
- Medline Plus. “Will health insurance cover the costs of genetic testing?”, *Medline Plus*, medlineplus.gov/genetics/understanding/testing/insurancecoverage/. Accessed 10 Sep. 2023.
- National Heart Lung and Blood Institute. “Cystic Fibrosis Diagnosis.” *National Heart Lung and Blood Institute*, www.nhlbi.nih.gov/health/cystic-fibrosis/diagnosis#:~:text=Genetic%20testing%20looks%20at%20your,chance%20you%20are%20a%20carrier. Accessed 7 Aug. 2023.
- Patient Advocate Foundation. “Where to Start If Insurance Has Denied Your Service and Will Not Pay.” *Patient Advocate Foundation*, 5 May 2020, www.patientadvocate.org/explore-our-resources/insurance-denials-appeals/where-to-start-if-insurance-has-denied-your-service-and-will-not-pay/#:~:text=Reasons%20that%20yo ur%20insurance%20may,treatment%20has%20not%20been%20proven.
- Schreiber, Allison. “Can Genetic Test Results Affect Insurance?” *Cleveland Clinic*, 29 Aug. 2021, health.clevelandclinic.org/could-the-results-of-a-genetic-test-affect-my-health-insurance-coverage/#:~:text=1%20%2F%201-,Could%20the%20Results%20of%20a%20Genetic%20Test%20Affect%20My%20Health,A%20genetic%20counselor%20explains.
- Stanford Medicine. “Huntington’s Disease.” *Stanford Health Care (SHC) - Stanford Medical Center*, 11 Sept. 2017, stanfordhealthcare.org/medical-conditions/brain-and-nerves/dementia/types/huntingtons-disease.html#:~:text=Prevention%20of%20Huntington’s%20disease,having%20children%20of%20your%20own.
- U.S. Equal Employment Opportunity Commission . “The Genetic Information Nondiscrimination Act of 2008.” *US EEOC*, 2008, www.eeoc.gov/statutes/genetic-information-nondiscrimination-act-2008.
- Vandette, Kay. “40 Percent of Diseases Are Influenced by Genetics, New Study Finds.” *Earth.Com*, 15 Jan. 2019, www.earth.com/news/40-percent-diseases-genetics/.



## How Does Music Influence Our Dreams? By Beliz Dora Valdiz

### Abstract

We all know that strong emotions and significant events during the day can shape dream scenarios, but can music have a similar effect? There is a potential avenue for exploring this connection-- for example, whether falling asleep to music generally improves our sleep, which would in turn influence the frequency of dreaming. Additionally, the valence of music (positive or negative) might influence our dream content. While doing that research, the context was "It was commonly observed that sounds in our environment, while we slept, could affect our dreams." Besides, the results we obtained as a result of the research are anticipated and these results will show that there's a relationship between music beats per minute (BPM) and dream valence (positivity or negativity). Prospective mechanisms linking music to dream quality and content may be related to heart rate, blood pressure, and anxiety levels. These factors may be additionally influenced by the type, BPM, or genre of the music a person listens to. The changes in the content of the dreams people have are the emotions that the music reflects on them, emotions such as happiness, excitement, sadness, and anger that we can actively feel inside us. In addition, we will make use of the physiological, psychological, and neurological mechanisms of music to be able to make a more accurate analysis during this study.

**Keywords:** *Dream, Music, Music Therapy, Neuroscience, Sleep.*

### Introduction

Sleep is a naturally recurring state of reduced consciousness and physical activity in most animals, including humans. Dreams are images, thoughts, or feelings that occur during sleep [1]. Dreaming can happen during any stage of sleep, but dreams are the most prolific and intense during the rapid eye movement (REM) stage. Dreams during REM sleep are typically more vivid, fantastical, and/or bizarre even though they may involve elements of waking life [2]. Dreams with intense emotions, whether positive or negative, tend to be more memorable as they leave a more profound impression. The content of dreams can be influenced by several factors, such as emotional events, preoccupations, memories, and creative activities [3]. Strong emotions and noteworthy events during the day can shape dream scenarios, leading to content that mirrors one's waking life experiences [4]. Effects of emotion on memory specificity: Memory trade-offs elicited by negative visually arousing stimuli. Dreams may also facilitate problem-solving and creativity by allowing the brain to explore new connections and possibilities [5].

Music can affect sleep quality positively by promoting relaxation and reducing stress, leading to improved sleep onset and continuity. Music is a form of art and cultural expression that combines sound, rhythm, and melody to create an emotional and aesthetic experience for the listener [6]. Music can evoke various emotions, trigger memories, and serve as a means of communication and storytelling [7]. Slow-tempo music with a low volume can help reduce heart rate, lower blood pressure, and decrease stress and anxiety levels, all of which can contribute to

better sleep [8]. Different types or genres of music can evoke a wide range of emotional responses, from happiness and excitement to sadness and nostalgia. Music enhances memory and learning by engaging multiple brain areas simultaneously, as musical rhythms and patterns aid in information retention and cognitive processing [9]. Additionally, music has therapeutic effects, as relaxing melodies can lower stress levels and promote emotional well-being, which can contribute to better sleep quality. Music therapy, a review of the potential therapeutic benefits for the critically ill [10].

Music becomes a conduit for healing and transformation in the hands of skilled music therapists. Music therapists should have knowledge of a wide variety of music history and the power of musical elements [11]. These practitioners harness the harmonious interplay of melodies, rhythms, and emotions to guide individuals on a profound journey of self-exploration and healing. In short, music can impact sleep by reducing anxiety and stress and promoting restful sleep. It can also shape dream experiences, with soothing music potentially leading to more pleasant dreams. Music therapists use their knowledge to help individuals achieve peaceful pre-sleep states, indirectly influencing sleep quality and dream content.

Both music therapy and the most fundamental measurement method are used to detect brain waves during sleep, which is an electroencephalogram (EEG). Studies have confirmed the effectiveness of this synchronization, leading to an increase in delta brainwaves connected with deep sleep. Delta brainwaves are a type of brainwave that is characterized by their slow frequency and high amplitude. They are one of the four primary types of brain waves, the others being alpha, beta, and theta waves. Each type of brainwave is associated with different states of consciousness and mental activity. They are most commonly observed during deep, dreamless sleep stages, particularly during the stage known as slow-wave sleep (SWS) or deep sleep [12].

## **Methods**

The field of neuroscience has provided valuable insights into the relationship between music, dreams, and sleep. Through rigorous research methods, researchers have been able to identify key findings and address common inquiries. This review sheds light on the connection between these three phenomena, providing a comprehensive understanding of the complex interplay between music, dreams, and sleep.

Studies focused on the interplay between music, dreams, and neuroscience employ a range of methodologies, encompassing psychological investigations, questionnaires, and dream diaries. Such research typically involves the exposure of participants to music before or during sleep, the maintenance of dream journals, and the administration of diverse neurological assessments. Typically, this research is conducted using a broad spectrum of study populations, including:

- *Healthy Adults:* The majority of research in this area centers on healthy adults. Studies reveal that music has a profound influence on dream content.

- *Healthy Non-Musicians:* The bulk of research in this field is centered on healthy non-musicians. Music possesses a profound ability to influence the content of dreams, with factors like tempo and emotional tone significantly shaping nocturnal experiences.
- *Healthy Musicians:* Musicians, a unique population with a deep connection to music, have also been a subject of study. The impact of music on the dream content of musicians is nuanced and may differ from that of non-musicians. Their musical expertise and familiarity with complex musical structures can lead to more intricate dream experiences. Neuroimaging studies indicate that the neural responses to music during dreams in musicians may exhibit distinct patterns compared to non-musicians.
- *Individuals with Sleep Disorders:* Studies targeting populations with sleep disorders, such as insomnia and sleep apnea, have sought to uncover how music interventions can enhance sleep quality and alleviate insomnia-related symptoms. Music-assisted sleep therapies have demonstrated promise in improving sleep architecture, known as the pattern of sleep as it progresses through various stages during a typical sleep cycle and reducing disturbances.
- *Trauma Survivors:* Trauma survivors, including those with post-traumatic stress disorder (PTSD), have been the focus of many studies. Music therapy, often combined with dream journaling, is utilized to help individuals process traumatic experiences and decrease the frequency of nightmares [13].
- Music therapy often improves sleep quality, reduces sleep latency, and decreases night awakenings for individuals with sleep disorders [14]. Music therapy enhances motor coordination, cognitive engagement, and emotional well-being for patients with neurological conditions like Parkinson's and Alzheimer's [15].
- Besides, research indicates that music can influence both the content and quality of dreams [16]. Factors such as tempo, emotional valence (negativity or positivity associated with a particular emotion and experience), and personal associations with music can shape the emotional tone and narrative of dreams [17]. For instance, a dreamer's deep personal connection to a slow, nostalgic song might lead to dream scenarios that mirror the song's emotions, with the dream's tempo and emotional valence shifting to match the dreamer's feelings and experiences within the dream.

Music has a powerful impact on human emotions, and it can be used to convey a wide range of feelings. In dreams, music can serve as a source of emotional expression, mirroring the

dreamer's emotional state. Some people report experiencing sadness, nostalgia, or even anxiety when they are listening to music, depending on the context and the specific music involved [19]. Music can also significantly reduce anxiety, stress, and other factors that can interfere with good-quality sleep [20]. However, the effectiveness of music in promoting better sleep can depend on various factors, including the type of music and individual preferences. Individual preferences play a significant role in determining how effective music is in influencing emotions and mood. People's emotional connections, musical tastes, cultural backgrounds, personal associations, and current psychological states all contribute to the effectiveness of music. What resonates emotionally is highly personalized and varies from person to person, making music a subjective and individualized experience. To use music effectively for emotional regulation or therapeutic purposes, it's essential to consider an individual's unique musical preferences and associations [21]. Slow-tempo, calming music can help relax the mind and reduce stress and anxiety. Music with a gentle melody and soothing harmonies can have a calming effect on the nervous system. Music with a slow tempo can help lower heart rate and blood pressure, promoting a more relaxed physiological state conducive to falling asleep.

### **Contextualizing**

The idea that dreams involving music are connected to positive emotions is a topic of interest in the field of dream research. While it is important to note that dreams are highly subjective experiences and can vary widely from person to person, there is some evidence to suggest a connection between music in dreams and positive emotions.

Additionally, studies have demonstrated that sleep plays a crucial role in maintaining overall health, particularly concerning the brain and the body. Insufficient or poor-quality sleep can have detrimental effects on various physiological processes and increase the risk of various health conditions [22]. So, the lesson to be drawn from this is that sleep is important for both brain development and the body. Music can have an impact on brain development during sleep in various ways. It can enhance memory consolidation (the process by which newly acquired information is converted into long-term memories in the brain), regulate emotions, influence dream content, and stimulate auditory processing (means to engage and activate the brain's ability to process and make sense of auditory information or sounds).

There is evidence that sleep is linked to the functioning of neural circuits involved in mood and emotion regulation. A review in "The Role of Sleep in Emotional Brain Function" [1] discusses the neurobiological mechanisms underlying the relationship between sleep and mental health, such as memory consolidation, emotion regulation, neurotransmitter balance (refers to the equilibrium of chemical messengers in the brain, like serotonin and dopamine), brain plasticity (signifies the brain's ability to adapt, rewire, and reorganize itself in response to new experiences, learning, and recovery from injury), stress hormone regulation (involves the control of hormones like cortisol, ensuring they are released appropriately to manage stress and maintain bodily equilibrium), frontal lobe activity (pertains to the functioning of the brain's frontal lobes, responsible for executive functions such as decision-making, problem-solving, and emotional

regulation), and neural network connectivity (refers to the interconnectedness of brain regions, highlighting how various parts of the brain communicate and collaborate to support different cognitive and emotional processes), all of which highlight the crucial role of sleep in maintaining mental well-being. It delves into the neurobiological mechanisms that underpin the connection between sleep and emotional brain processing, investigating how sleep affects the brain's ability to handle emotions.

On top of that, sleep disturbances are often related to mental health disorders such as depression, anxiety, and bipolar disorder and can impact stress management and resilience [23]. However, chronic poor sleep can also increase the risk of developing these conditions by disrupting neurobiological processes shared between sleep regulation and mental health. Sleep-related functioning in euthymic patients with bipolar disorder, patients with insomnia, and subjects without sleep problems [23].

Moreover, research in neuroimaging has demonstrated the brain-activating effects of soothing music, particularly in regions associated with stress reduction and relaxation like the prefrontal cortex and limbic system. The term "brain-activating" typically refers to activities, stimuli, or substances that stimulate or activate the brain's neural activity. In addition, music with a slow tempo of around 60-80 beats per minute can synchronize with the brain's natural rhythms, aiding in the transition from wakefulness to sleep [24]. Moreover, music has a direct impact on the amygdala, a crucial center for emotional processing, such as emotional activation, emotion regulation, enhanced memory, and stress reduction. It is possible to say, "To define emotional activation and regulation, music has the power to evoke a wide range of emotions in listeners." [25, 26]. Positive, calming music can help individuals manage emotional stressors that may otherwise hinder sleep initiation [27]. It should be taken into consideration that the impact of music on sleep is subject to personal variation and can be affected by individual preferences, musical inclinations, previous encounters, and underlying neurological conditions, including sleep disorders.

## **Conclusion**

The connection between music and dreaming varies between individuals.

Although some empirical studies imply that there is a relationship between music and dreaming, others do not support this conclusion. Researchers measured the frequency and the dream content during sleep with music compared to sleep without music.

This literature review sheds light on the potential influence of music, with its diverse qualities and genres, on the content and quality of our dreams. The interplay between music and the dream world is complex, with factors such as tempo, emotional valence, and personal associations with music playing a role. The connection between music and dreams presents intriguing possibilities for future studies that delve deeper into the specific mechanisms underlying this relationship.

Additionally, the therapeutic potential of music in the context of sleep disorders and mental health is noteworthy. Slow-tempo, calming music can effectively reduce anxiety, and

stress, and promote relaxation; thus enhancing the conditions conducive to sound sleep. Music therapists, with an understanding of music's profound impact, have harnessed its power to guide individuals on journeys of healing and self-exploration.

Recognizing the significance of sleep in maintaining overall health and well-being, it is essential to acknowledge the intricate neural and emotional processes that occur during this essential state. Sleep disturbances have been linked to various mental health disorders, further emphasizing the importance of exploring avenues like music therapy to improve sleep quality and emotional regulation.

In essence, the relationship between music, dreams, and sleep is multifaceted and dynamic, with each element influencing the other in intricate ways. As our understanding of this connection continues to evolve, it presents exciting prospects for improving sleep, enhancing emotional well-being, and harnessing the therapeutic potential of music in our lives.

## Works Cited

1. Goldstein, A.N., Walker, M.P. The role of sleep in emotional brain function. *Annual Review of Clinical Psychology*. (2014); 10: 679-708.  
<https://doi.org/10.1146/annurev-clinpsy-032813-153716>
2. Hobson, J.A., Stickgold, R., Pace-Schott, E.F. The neuropsychology of REM sleep dreaming. *Neuroreport*. (1998); 16: 9 (3): R1-R14.  
<https://doi.org/10.1097/00001756-199802160-00033>
3. Bower, G.H. Mood and memory. *American Psychologist*. (1981); 36 (2): 129-148.  
<https://doi.org/10.1037/0003-066X.36.2.129>
4. Kensinger, E.A., Garoff-Eaton, R.J, Schacter, D.L. Effects of emotion on memory specificity: Memory trade-offs elicited by negative visually arousing stimuli. *Journal of Memory and Language*. (2007); 56 (4): 575-591. <https://doi.org/10.1016/j.jml.2006.05.004>
5. Olbrich, K.I., Schredl, M. Music and dreams: A review. *International Journal of Dream Research*. (2019); 12(2): 67-71. <https://doi.org/10.11588/ijodr.2019.2.64480>
6. Brattico, P., Brattico, E., Vuust, P. Global sensory qualities and aesthetic experience in music. *Frontiers in Neuroscience*. (2017); 11: 159. <https://doi.org/10.3389/fnins.2017.00159>
7. Sleep Foundation (2023, September 1). Music and sleep: Can music help you sleep better? Retrieved August 01, 2023, from <https://www.sleepfoundation.org/noise-and-sleep/music#:~:text=Music%20improves%20sleep%20through%20calmingwith%20frustration%20and%20sleepless%20nights.>
8. Lai, H.L., Good, M. Music improves sleep quality in older adults. *Journal of Advanced Nursing*. (2006); 53 (1): 134-144. <https://doi.org/10.1111/j.1365-2648.2006.03693.x>
9. Jäncke, L. Music, memory and emotion. *Journal of Biology*. (2008); 7: 21.  
<https://doi.org/10.1186/jbiol82>
10. Mofredj, A., Alaya, S., Tassaioust, K., Bahloul, H., Mrabet, A. Music therapy, a review of the potential therapeutic benefits for the critically ill. *Journal of Critical Care*. (2016); 35: 195-199. <https://doi.org/10.1016/j.jcrc.2016.05.021>
11. Master's in Special Education Degree Program Guide (2021, November 9). Job profile: Music therapist. Retrieved August 24, 2023, from <https://www.masters-in-special-education.com/job-profile/music-therapist/>
12. Dickson, G.T., Schubert, E. How does music aid sleep? Literature review. *Sleep Medicine*. (2019); 63: 142-150. <https://doi.org/10.1016/j.sleep.2019.05.016>
13. Habukawa, M., Uchimura, N., Maeda, M., Kotorii, N., Maeda, H. Sleep findings in young adult patients with posttraumatic stress disorder. *Biological Psychiatry*. (2007); 62(10): 1179-1182. <https://doi.org/10.1016/j.biopsych.2007.01.007>
14. Lin, D., Huang, X., Sun, Y., Wei, C., Wu, A. Perioperative sleep disorder: a review. *Frontiers in Medicine* (2021); 8. <https://doi.org/10.3389/fmed.2021.640416>

15. Brancatisano, O., Baird, A., Thompson, W.F. Why is music therapeutic for neurological disorders? The therapeutic music capacities model. *Neuroscience & Biobehavioral Reviews*. (2020); 112: 600-615. <https://doi.org/10.1016/j.neubiorev.2020.02.008>
16. Sand, S., Levin, R. The effects of music on dream content: An empirical analysis. *Dreaming*. (1997); 7 (3): 215-220. <https://doi.org/10.1037/h0094476>
17. Thompson, W.F., Bullot, N.J., Margulis, E.H. The psychological basis of music appreciation: Structure, self, source. *Psychological Review*. (2023); 130 (1): 260-284. <https://doi.org/10.1037/rev0000364>
18. König, N., Fischer, N., Friedemann, M., Pfeiffer, T., Göritz, A.S., Schredl, M. Music in dreams and music in waking: An online study. *Psychomusicology: Music, Mind, and Brain*. (2018); 28 (2): 65-70. <https://doi.org/10.1037/pmu0000208>
19. Liljeström, S., Juslin, P.N., Västfjäll, D. Experimental evidence of the roles of music choice, social context, and listener personality in emotional reactions to music. *Psychology of music*. (2013); 41 (5): 579-599. <https://doi.org/10.1177/0305735612440615>
20. Etkin, A., Wager, T.D. Functional neuroimaging of anxiety: a meta-analysis of emotional processing in PTSD, social anxiety disorder, and specific phobia. *The American Journal of Psychiatry*. (2007); 164 (10): 1476-1488. <https://doi.org/10.1176/appi.ajp.2007.07030504>
21. Lin, S.T., Yang, P., Lai, C.Y., Su, Y.Y., Yeh, Y.C., Huang, M.F., Chen, C.C. Mental health implications of music: Insight from neuroscientific and clinical studies. *Harvard Review of Psychiatry*, (2011); 19 (1): 34-46. <https://doi.org/10.3109/10673229.2011.549769>
22. Chattu, V.K., Manzar, M.D., Kumary, S., Burman, D., Spence, D.W., Pandi-Perumal, S.R. The global problem of insufficient sleep and its serious public health implications. *Healthcare*. (2018); 7 (1): 1. <https://doi.org/10.3390/healthcare7010001>
23. Harvey, A.G., Schmidt, D.A., Scarnà, A., Semler, C.N., Goodwin, G.M. Sleep-related functioning in euthymic patients with bipolar disorder, patients with insomnia, and subjects without sleep problems. *American Journal of Psychiatry*. (2005); 162 (1): 50-57. <https://doi.org/10.1176/appi.ajp.162.1.50>
24. Luce, G.G. *Biological Rhythms in Psychiatry and Medicine*. Public Health Service Publication. (Public Health Service Publication No. 2088). U.S. National Institute of Mental Health (1970). ISBN:978-0-4862-2586-9
25. Frühholz, S., Trost, W., Grandjean, D. The role of the medial temporal limbic system in processing emotions in voice and music. *Progress in Neurobiology*. (2014); 123: 1-17. <https://doi.org/10.1016/j.pneurobio.2014.09.003>
26. Vuilleumier, P., Trost, W. Music and emotions: from enchantment to entrainment. *Annals of the New York Academy of Sciences* (2015); 1337 (1): 212-222. <https://doi.org/10.1111/nyas.12676>
27. Trahan, T., Durrant, S.J., Müllensiefen, D., Williamson, V.J. The music that helps people sleep and the reasons they believe it works: A mixed methods analysis of online survey



## **A Double-edged Sword on Neutrality: Analyzing South Africa's Stance in the Russia-Ukraine War By Victor Awofeso**

### **Abstract**

The Russia-Ukraine war is one with ongoing incidences that have daunting consequences on a global scale. From political and economic ties bound to the history and outcome of the war, countless countries are faced in its backdrop, with severe economic and political repercussions to think of when making decisions. With many Western powers having condemned Russia and imposed sanctions on the country, South Africa is one of the few countries with different views towards the Russia-Ukraine war. Under a veneer of a neutrality stance, South Africa is a particularly special country to analyze within its views on the Russia-Ukraine war, as the country is anything but neutral because of its reliance on and friendship with Russia.

A comparative examination of South Africa's relationship with Ukraine and Russia to provide a more coherent context as to where South Africa's inconclusive stance and behavior in the Russia-Ukraine war stems from, as well as an explorative analysis through South Africa's actions in the wake and amid the Russian invasion of Ukraine and its impact on the state, this paper seeks to argue the bias that underlies the neutrality stance of South Africa. Despite claims that South Africa is neutral in the Russia-Ukraine war, the actions that it has taken would suggest otherwise; in retrospect, South Africa implicitly supports Russia despite its neutral stance. As a result, new systematic disputes emerge and a political divide within South Africa and through an international lens towards the country's position in the Russia-Ukraine war.

### **Overview**

As a historically imbued conflict, the Russia-Ukraine war still holds much relevance in today's political climate. With thousands dead and millions of Ukrainians displaced, the effects of the Russia-Ukraine war are profoundly intricate and have engulfed almost every international power into having a say in the war. With as many repercussions through the condemnation and sanctioning of Russia, many Western powers from the United States, Australia, the United Kingdom, and more have been very vocal in their support for Ukraine and angst against Russia. However, among the countries with a say in the war, a select few of them have either shown their support for Russia or proclaimed a stance of neutrality in the wake of United Nations (UN) general assembly sessions that called into the interventions of other countries. With several African nations falling under this proclamation of neutrality, their alliance and relationship with Russia are shown to be very influential in their inability to condemn Russia, out of fear of upsetting the nuclear-dominating country itself, and full-on supporting the nation, out of fear of upsetting the mighty west and inviting sanctions. Instead of blaming Russia for the war, these countries saw NATO as the aggressor for the invasion (Ajala, 2022, p. 146). South Africa is a country that strongly views Western organizations as the cause of the war while doing anything in its power to avoid stepping on the toes of its Russian benefactor. As a democratically constituted country that has failed to criticize Russia, South Africa is unique for its hypocritical

ability to inadvertently support an imperialist country anathematic to the principles it was founded on (Seekings & Saunders, 2022, p. 118a). With numerous votes abstaining from UN sessions and inconclusively blaming Russia for its invasion (Fabricius, 2022a), South Africa is a nation that has proclaimed an ambiguous neutral stance that is shrouded under its veneer tie with Russia. Despite UN South African ambassador Mathu Joyini's excuse for South Africa's abstention to be due to elements within the resolution that did not provide a peaceful solution to the war (Fabricius, 2022b), it is self-evident that a scrutinization of a resolution is only to cover up the country's ambivalence because of its ties with Russia (Gottschalk, 2022a). These ties are vital when analyzing South Africa's inconclusive stance on the Russia-Ukraine war, for the nation had built a tie with Russia that forged an inconspicuous alliance shrouded with feelings of indebtedness and support for multilateralism (Gottschalk, 2022b). Though these historical ties will be linked to economic relations between Russia and South Africa, they are relatively limited and thus do not hold many reasons for South Africa's ambivalence to the war (McKaiser, 2022a).

### **History of South Africa's ties with Russia**

The history between South Africa and Russia could be dated to 1897 when the nation was still in the USSR and Tsar Nicholas II considered establishing a Russian consulate in the South African Republic (later referred to as Transvaal) because of a "growing importance of the African continent for the people of Europe and important political questions" (South African History Online, 2019a).

Leading up to the 20th century, relations between South Africa and the Soviet Union were further authenticated, especially during apartheid and white-minority rule in South Africa. South Africa received assistance (in the forms of money, weapons, and other military aid such as naval, air force, guerilla, and conventional warfare training) from the former Soviet Union to anti-apartheid freedom fighters. Support also came from educational facilities, money for publications, travel, and more (Seekings & Saunders, 2022, p. 121a). The establishment of the Communist Party of South Africa (CPSA) in 1921 - which would ultimately dissolve into the South African Communist Party in the 1950s - resulted in strengthened ties with the African National Party (ANC) – and South Africa's current leading political party - considering both organizations repressed the racially politicized composition of South Africa. Both these organizations were given essential aid in the increase of USSR influence within South Africa, resulting in the Umkhonto we Sizwe (MK) "engage in armed struggle against the apartheid regime" (Seekings & Saunders, 2022, p. 121b).

However, when the Sharpeville Massacre of 1960, which claimed the lives of 69 black people, in South Africa occurred, the banning of the ANC and Pan Africanist Congress would leave no other options than for relations between anti-apartheid officials and the Soviet Union's official agencies to be strengthened. Talks with the Communist Party of the Soviet Union were held by South African officials Yusuf Dadoo and Vella Pillay in July 1960 in Mosco, informing the party about South African developments (South African History Online, 2019b). Hence, the Soviet Union remained the state "that fundamentally refused contacts with the criminal

[apartheid] regime” (Davis, 2022a). The extent of this aid exceeded that from the African Union or anywhere else – specifically the United States in the West (the country labeled the ANC a “terrorist organization” and Nelson Mandela, the liberation hero, a “terrorist” until 2008) (Mohamed, 2023a). However, it should be noted that Scandinavian donations did exceed that of the Soviet Union from the end of the 1970s, only to the extent of the donations coming in the form of peaceful aid, as opposed to that of the Soviets (Gottschalk, 2022c).

More recently, under ex-South African President Jacob Zuma, in hopes of attracting more Russian investment in the country, South Africa became a partner of Russia in the BRICS group - formed by Brazil, Russia, India, China, and South Africa in hopes of promoting trade and security ties between themselves - in December 2010 (McKaiser, 2022b). Paying R25.5 billion to be a part of BRICS, it is unclear whether this business decision has benefited South Africa in the long run (Davis, 2022b). This could be seen as the alliance included a failed \$76 billion nuclear project between South Africa and Russia, resulting in the firing of South African finance minister Nhlanhla Nene (Weiss & Rumer, 2019).

Despite the noteworthy social aspects of the history between Russia and South Africa, the economic aspects are pretty lacking and hence irrelevant. South Africa’s trade links with Russia are relatively limited since the country only made up less than 0.4% of the total goods exported in 2021. Despite its involvement in BRICS, only China and India made it among South Africa’s top 10 countries of exports; Russia was not even in the top 30 (McKaiser, 2022c). Instead, 40% of South Africa’s wheat imports came from countries like Lithuania, Argentina, Poland, Australia, the United States, and Latvia (Nelson, 2022a). In 2020, South African exports to Russia were \$587 million, while imports were \$506 million, less than 1% (0.7%) of total imports (Business Tech, 2022a). Significant products imported into South Africa included sunflower oil, wheat (\$131.9), and fertilizer (\$57.8) (Duho et al. 26). From 2016 to 2020, South Africa imported 1.8 million tons of wheat per year, on average; half of the annual wheat consumption needs. Wheat imports from Russia and Ukraine averaged 34% and 4%, respectively (Business Tech, 2022b). Therefore, the virtually nonexistent economic ties between South Africa and Russia are less likely to be influential or at stake when analyzing why South Africa’s views towards the Russia-Ukraine war are as ambiguous as they are.

Nevertheless, it is no surprise why the continuation of historical ties between South Africa and Russia has been argued to be imperative in South Africa’s supposed biased view towards the Russia-Ukraine war as the nation was able to transition from days of oppression and separation to a constitutional democracy (Gottschalk, 2022d); thanks to help from the Soviet Union that has had long-standing repercussions and feelings of “pay-back” emanating from the political decisions of South Africa about the war.

### **History of South Africa with Ukraine**

Before the Russia-Ukraine war, although relations between South Africa and Ukraine were mainly tied to economic and social purposes, the history between South Africa and Ukraine, although unprecedented, was still existent, even if implicit. Amid the fight against

apartheid that the Soviet Union so explicitly assisted South Africa in, Ukraine also played a key role as most MK (Umkhonto we Sizwe, the paramilitary wing of the ANC [South African History Online, 2022c]) soldiers had trained in Ukraine while many ANC members likewise studied in Ukraine (Seekings & Saunders, 2022, p. 121c).

In hopes of increasing tourism and social aspects in both countries, South Africa established an embassy in Kyiv, Ukraine, in October 1992. Moreover, in 1995, Ukraine established an embassy in Pretoria, the capital city of South Africa (“South Africa-Ukraine relations,” 2022a). Additionally, both countries have trade relations, playing into the economic aspect of the relationship between South Africa and Ukraine. In 2008, South Africa became the second country – after Ghana – in Africa to export the most products to Ukraine. Trade grew 5.4 times to \$375.1 million. 13 years later, in 2021, South Africa had exported \$28.98 million and imported \$48.67 million worth of goods going to and coming from Ukraine. (“South Africa-Ukraine relations,” 2022b). The main products sought from Ukraine include wheat (\$11.7 million), hot-rolled iron (\$3.97 million), and malt (\$2.68 million). From South Africa, however, the main export products include Tanned equine and bovine hides (\$29.6 million), cars (\$13.3 million), and citrus at \$8.49 million (Garcia, 2021).

### **Impact on South Africa**

For the most part, South Africa has mainly faced the impacts of the Russia-Ukraine war through its economy – as opposed to other aspects like tourism - in both positive and negative ways. Despite having relatively low trade with Russia and Ukraine, South Africa’s economy was still bound to face some rumbles as Russia and Ukraine have strong ties through their large export shares with the global cereal markets, which, as a result, affects commodity prices such as wheat and corn, caused price surges in South Africa ever since Russia began its invasion. However, these price surges do not mean shortages will occur, as Agriculture Business Chamber Chief Economist Wandile Sihlobo stated. It indicates that low-income households are bound to struggle for essential commodities, leading to a surplus in goods rather than a shortage. This can be seen with small farmers who, due to the doubling in the cost of fertilizers (typically exported from Russia), cannot access fertilizers because of their low standard of living. Socially, this inflation in commodity goods has caused much social unrest, accounting for the recent riot outbreaks in South Africa (Access Bank, 2022).

South Africa also saw rising diesel and petrol fuel costs amid sanctions imposed on Russia by the USA and the UK (Stoddard, 2022a) and increased tensions in the Russia-Ukraine war. The Brent crude oil price exceeded \$100 per barrel for the first time since 2014 (Business Tech, 2022c), and the petrol price is also set to climb from 146 cents a liter to R21.60, a 7% increase (Stoddard, 2022b). However, despite the inflation, considering South Africa is a significant exporter of maize (South Africa projected 16.32 million tons of maize in 2021, the second-biggest crop on record), the economy could benefit, considering Ukraine has been South Africa’s biggest maize competitor. Hence, with supplies curtailed in Ukraine, South Africa could become the dominating maize exporter for many countries (Nelson, 2022b). South Africa could

also benefit from increasing the price of its other vital exports, such as gold and palladium, since Russia is the world's largest palladium producer, with South Africa second (Business Tech, 2022d).

In the Political realm, the impact of the war has resulted in a polarizing divide between the main parties in South Africa, the ANC and the Democratic Alliance, regarding how the country should proceed with actions towards the war. As opposed to an official abstention in the war, South Africa's internal political affairs have been neutral, as political leaders loudly voiced their support/angst for Russia (Comins, 2022a). The ANC has been heavily opposed and criticized by the Democratic Party as they aim for the ANC to support Ukraine. Condemning the country's neutral stance to the war, the Democratic Alliance's shadow minister for international relations, Darren Bergman, criticized South Africa on its hypocritical stance, considering how hard the country fought the repressive apartheid regime with the help of global powers yet not repaying the favor. "An abstention or voting for Russia is pretty much the same language. It is a vote against Ukraine. It is a vote against peace and condonation of the violence in Ukraine," Bergman said" (Stark, 2022). With other party members voicing their disdain for South Africa's stance, the political divide of South Africa has been rampant in the general population of South African society. However, the government still urged "all South Africans not to take sides [in] the conflict between Russia and Ukraine, as this could go against our principles. In addition, South Africa has good bilateral relations with both countries" (Comins, 2022b).

Such a response from the Democratic Alliance was synonymous with that of Western powers when analyzing the decision of South Africa to abstain through an international lens. Its ambiguity and inexplicit condemnation of Russia's invasion of Ukraine has resulted in pressures from the West for South Africa to reconsider its bond with Russia at the expense of relationships with other powers, primarily the United States (Gramer, 2023a). When a delegation of South African officials went to Capitol Hill in hopes of reinforcing its relationship with the United States amid frustrations from U.S. officials and lawmakers over the country's relationship with Russia and potential threats to U.S. national security, it was clear that relations between South Africa and the United States had been affected negatively (Gramer, 2023b). Despite attempts by Rama Yade, the senior director of the Africa program at the Atlantic Council, to reconcile the relationship between South Africa and the United States by arguing that "the U.S.-South African relationship is too important for either side to let it collapse, both in terms of their mutually beneficial trade ties and South Africa's strategic importance as a political and economic powerhouse in Africa" (Gramer, 2023c), other political opinions certainly did not agree with this claim. "Despite past cooperation and potential trade benefits, South Africa's political actions—which baldly threaten U.S. national security interests—have outweighed the traditional stabilizers and benefits in the relationship," stated an anonymous congressional aide (Gramer, 2023d).

Furthermore, when South Africa was present at the 10th Moscow Conference on International Security, it stood as a reason for the solidarity of South Africa at the hands of Russia and the failure of any international power, specifically the United States, to alter this

otherwise. As stated by Russian Defense Minister Sergei Shoigu, it was “very encouraging that prominent military commanders from our friendly states — Burundi, Cameroon, Guinea, Mali, Sudan, Uganda, Chad, Ethiopia, and the Republic of South Africa — are present in this hall today, ... We [Russia] appreciate your support and intend to increase cooperation on mutually beneficial projects... Despite attempts of the US and NATO to isolate Russia once again, your participation in the forum is a visible confirmation that these plans have collapsed.” (Fabricius, 2022). Hence, there is no doubt that South Africa’s negligent stance has failed to garner the country's support nationally and internationally. With a provocation at the United States and NATO, of which South Africa has also participated, its “friendly” relationship with Russia bound on historical ties will only threaten current ties within the United States, challenging the country’s interests “unfavorably” (Gramer, 2023e).

### **Analysis**

As aforementioned in the abstract, South Africa proclaimed a neutral stance in the war in correspondence to also abstaining from a vote at three UN general assembly meetings condemning Russia’s annexation of Ukrainian territories back in October (Mohamed, 2023b) because the benefit that neutrality serves is that “we can talk to both sides,” South African President Cyril Ramaphosa stated (Nathan, 2022). Despite attempts by Ramaphosa to mediate in the war, as he did by hosting and backing peace talks between the Ethiopian government and rebels from its Tigray region, he blamed U.S. President Joe Biden by stating that the Russia-Ukraine war could have been avoided if Biden had agreed to meet with Russian President Vladimir Putin unconditionally days before the Russian attack on Ukraine (Fabricius, 2022). The South African president also blamed NATO by claiming that the alliance ought to have “heeded the warnings from amongst its own leaders and officials over the years that its eastward expansion could lead to greater, not less, instability in the region” (Mohamed, 2023c). By equally attacking Russia’s threat, Ukraine’s alliance, South Africa’s full support, as a result, would not go along with that of Ukraine but of that of Russia, resulting in an imbalance of the neutrality scale South Africa proclaimed. This perspective could further be accredited when the Nelson Mandela Foundation came out with a statement over the Russian invasion of Ukraine which corresponded with that of the South African government. Like the ANC, the foundation failed to condemn the Russian invasion but instead “proceeded to list the faults of the USA and its allies in the West” (Seekings & Saunders, 2022, p. 125). Suppose an organization founded on the premise of a leader against apartheid whom the Soviet Union helped inadvertently avoided the principles it fought against by not condemning Russia outright. In that case, it stands as a reason for the immense influence the Soviet Union had on South Africa during the apartheid era. Therefore, it is possible to interpret this unwillingness to denounce Russia as a manifestation of that influence and the need to pay back Russia’s prior empire.

In addition to historical ties, there might still be numerous reasons for South Africa’s ambivalence towards the Russia-Ukraine control. One possibility is for Ramaphosa to retain his power within South African society by allying himself with the Russian-friendly party, ANC. In

2019, Russian operatives planned to influence South Africa's general election to strengthen the Governing ANC through documents promising to support the ANC and counteract the pro-western Democratic Party, as well as videos and public rhetoric pro-ANC (Business Tech, 2019). Moreover, in an era where implicitly supporting Russia has resulted in withering relationships with Western powers like the United States, South Africa's inability to look past its historical indebtedness to Russia can be attributed to one of the many factors that have made the ANC the leading party in South Africa, as well as Ramaphosa.

Another probable reason could be for South Africa to prevent ending up on the wrong side of the tracks with a nuclear-dominating nation like Russia. When South Africa initially called for Russia to "immediately withdraw its forces from Ukraine in line with the United Nations Charter" - before retracting this statement and abstaining from multiple UN sessions condemning Russia - on February 24, South African Defense Minister Thandi Modise attended the Russian ambassador's residence that evening in celebrating "Russia's Defender of the Fatherland Day, a celebration of the Russian army" (Seekings & Saunders, 2022, p. 118b). It is no surprise then when South Africa's renegade on bringing Russia accountable for its actions seems more to be in line with preserving the friendly relationship with Russia solely for South Africa's benefit - as opposed to Ukraine's - despite Russia's abstinence in protecting human rights, of which South Africa stands against. More recently, in March 2023, South Africa announced that Russian President Vladimir Putin would not attend a BRICS summit -held from August 22nd to 24th-amid an arrest warrant issued against the Kremlin on the grounds of crimes against humanity by the International Criminal Court (Gramer, 2023f). This was a unique predicament that South Africa found itself in because had the country not stated that Russia would not be attending, South Africa would have been required to arrest Putin as it was a signatory to the Rome Statute, which founded the ICC (Gramer, 2023g). Moreover, South Africa would have threatened the relationship between Russia and South Africa, even to the extent of the arrest being "tantamount to a declaration of war." "It would be inconsistent with our constitution to risk engaging in war with Russia," Ramaphosa stated (Gramer, 2023h). For South Africa to charade and dance around its principles against human rights violations by indirectly supporting Russia and not taking tangible actions in being a morally recognizable country on Russia's actions towards the war is yet again a more evident reason as to why South Africa's neutrality stance is just another facade to strengthen the friendship between the two countries and avoid a war that could affect any future opportunities from South Africa to receive support from the more assertive Russia.

On top of this, to tip the scales in indiscreetly supporting Russia, South Africa conducted joint military drills and navy exercises, named Operations Mosi-2 (smoke), with live ammunition on targets with Chinese and Russian warship natives, for ten days during February 2023 in the Indian Ocean (Express, 2023). This event, occurring over the first anniversary of the war in Ukraine, was criticized by the Democratic Alliance party as they stated that the exercises contradicted South Africa's neutrality stance, further polarizing the two parties in South Africa. "It is becoming increasingly clear that the South African government is openly siding with

Russia," stated Darren Bergman, a lawmaker with the Democratic Alliance party (The Moscow Times, 2023). He also noted that the stunt would "definitely have an impact when it comes to trade agreements and aid... any further exclusion from the international community is going to be hugely damaging" (Express, 2023). Although claims Naledi Pandor, the Minister of International Relations and Cooperation of South Africa, that "all countries conduct military exercises with friends worldwide," and that the exercises were "part of a natural course of relations between countries," adding that Pretoria should not be denied "the right to participate" in the drills, (express, 2023) the word choice of "friends" as well as the timing in which this event occurred are very revealing and self-evident to South Africa's hypocrisy and hide under its neutrality stance to support Russia. To prevent the supplementary defense provided by Pandor amid the controversies, South Africa could have chosen to conduct these training exercises at another time, preferably in the foreseeable future, when the war had ended. Moreover, with these exercises and the word choice of "friends," as Pandor used, the Russian army is inevitably benefitting from its history with South Africa and getting better at its combatting skills; this means less of an advantage for the Ukrainian forces as South Africa. Hence, if South Africa did well to stake a neutral stance in the war, the timing of these training exercises suggested otherwise and just pointed to the same conclusion that despite attempts to proclaim neutrality and goals to peacefully help mediate the war, South Africa, through its action, is not doing what it declared as it is inadvertently helping out Russia, rather than not helping at all to justify its neutrality status fully.

Back in December 2022, when tensions between South Africa and the United States reached a halt amid a controversy regarding a Russian cargo ship on South African docks, the South African excuse was only the more reason as to why South African stance is not as neutral as it proclaims it is, threatening relations with the United States as a result. Reuben Brigety, a U.S. Ambassador to South Africa, accused South Africa of "secretly smuggling arms to Russia through a cargo ship connected to a sanctioned Russian Company" (Gramer, 2023i). Lady R, as the cargo ship was called, was seen departing from the Simon's Town Naval Base between the hours of 8-10 p.m. after three nights of "highly guarded activity" with unidentified cargo moved on and off the ship in the presence of "armed officials" (O'Regan, 2022a). With the ship's automatic identification system offline, which would have otherwise provided the ship's "position, identification and other information to other vessels and coastal authorities," the purpose of the Russian-operated ship on South African docks was unclear. The ship was said to go under an investigation upon the South African government denying the accusations. Still, the so-called "investigation" was since wrapped up, with no conclusions released to the public, despite pressure (Gramer, 2023j) from the Department of Defense, the South African National Defense Force, nor the navy for the arrival of the ship (O'Regan, 2022b). Suppose South Africa cannot disclose the purpose of a Russian ship on its docks. In that case, it is a reason for the secrecy shrouded under the South African government, especially about Russia. Hence, if this secrecy can further polarize the South African government and the trust of the general population, it is only more affirmative the power that Russia has over the country; it is, therefore,



equivalent to why the government refuses to condemn Russia, for its benefit and not for the sake of Ukraine and its population which the Russian invasion has violated. Since South Africa also refuses to listen to what its international counterparts are doing in sanctioning and condemning Russia, it leaves the country at risk of sanctions imposed on it for supporting Russia under the facade of neutrality (Bartlett, 2023).

Attempts and moves made by international powers will not persuade South Africa to change its stance and condemn Russia on the same colonialist repressive grounds that are anathematic to what the currently established democracy fought against (McKaiser, 2022d). Though it is irrefutable that this was primarily achieved by the Soviet Union, its long historical ties ought to have no meaning in current days when Russia is doing no good but reliving its old empirical days, and South Africa keeps coming up with ways to excuse Russia's behavior effectively. Instead, it poses to be more explicit that through several actions made by the South African government, its "neutral" stance is a sheer facade under the need to preserve the friendly relationship with Russia and enjoy the diplomatic and military benefits that are associated with it, all while looking past the horrors committed by the Russian government in Ukraine. When Russia accounts for a mere 0.4% of South Africa's foreign trade (Thamm, 2019), with South Africa holding over R77 billion worth of investments in Russia and the reciprocated investment not amounting to one-third of that amount (Davis, 2022c), it is a further testament to the relationship between South Africa and Russia being especially sustained by South Africa for no other reason than being like a friend to a person who is a bully to others solely for the protection that the friendship offers.

### **What Next?**

As for South Africa, its neutral stance cannot be upheld much longer before its hypocritical basis on the principles it is supposedly supposed to believe in results in more internal and outward pressures and ruins everything for South Africa. The country needs to realize that the same country to help it fight the oppressive system of apartheid is not the same friend that it should still be looking up to with high - and even fearful - regards. With more human violations committed by the Russian government amid the Russia-Ukraine war than one can count, in the name of a refuted neo-imperialism by the Russian government (Davis, 2022d), it is not enough for South Africa to select which wars to have an opinion in, and which war stay silent about, with no justification other than the one that is shrouded under the historical indebtedness to the Soviet Union. Suppose many international powers can have a moral conscience about the violations committed by the Russian government and condemn Russia. In that case, the extent to which other global powers profoundly disdain the Russian invasion of Ukraine should be evident. Therefore, as a democratically constituted country founded on the principles of equality and human dignity, there should be no reason why South Africa cannot do the same. The country needs to wake up and abandon its so-called friend for the nuclear-possessing bully that it is through condemning Russia and abandon the loyalties that have blinded the nation into overlooking the atrocities committed by the Russian government.

For this war to end, cooperation among nations/organizations (Russia/NATO) is vital to make steps moving toward the end of the Russia-Ukraine war. If no considerations are willing to be evaluated due to uncooperating, the war will only be prolonged with an increasing death toll. An indicator of this can be seen in the Russian army, which does not show any signs of backing down anytime soon, as seen by the rallying support for the Russian Soldiers in Moscow. If anything, this indicates that the Russian army is still fully mobile and only ready to stop if they achieve their goal. Hence, it is pivotal that if at least cooperation does not work to settle the war, Ukraine gets much better help in protecting its territories from major powers like the United States and NATO; the current help is insufficient. Suppose full support was targeted towards aiding Ukraine. In that case, the overwhelming combat would be enough to slowly derail Russia and make it come to its senses to renegotiate the terms of the war so that it may finally end. This war's impacts on millions are profound; morality and human compassion must be acknowledged to prevent further human horrors.

## Works Cited

- Access Bank. "The Ukraine-Russia Conflict: How Is South Africa Affected? - Access Bank South Africa." Access Bank South Africa, 23 Nov. 2022, <https://southafrica.accessbankplc.com/knowledge-and-networks/the-ukraine-russia-conflict-how-is-south-africa-affected/>
- Ajala, Olayinka. "The Case for Neutrality: Understanding African Stances on the Russia-Ukraine Conflict." *Journal of Military and Strategic Studies* 22.2 (2022).
- Banya, Nelson. "South Africa Sees Food Inflation, Opportunity From Russia-Ukraine War." Reuters, 8 Mar. 2022, [www.reuters.com/world/africa/south-africa-sees-food-inflation-opportunity-russia-ukraine-war-2022-03-08](http://www.reuters.com/world/africa/south-africa-sees-food-inflation-opportunity-russia-ukraine-war-2022-03-08).
- Bartlett, Kate. "South Africa Criticized for Hosting Russian Warships Amid Ukraine War." VOA, 18 Jan. 2023, [www.voanews.com/a/south-africa-criticized-for-hosting-russian-warships-amid-ukraine-war-/6923375.html](http://www.voanews.com/a/south-africa-criticized-for-hosting-russian-warships-amid-ukraine-war-/6923375.html).
- Business Tech. "Documents Show Alleged Russian Plot to Interfere in South African Elections: Report." *BusinessTech.co.za*, 2015, [businessstech.co.za/news/government/315678/documents-show-alleged-russian-plot-to-interfere-in-south-african-elections-report/](http://businessstech.co.za/news/government/315678/documents-show-alleged-russian-plot-to-interfere-in-south-african-elections-report/).
- Business Tech. "How Russia's Invasion of Ukraine Will Hit South Africa." 28 Feb. 2022, [businessstech.co.za/news/finance/563176/how-russias-invasion-of-ukraine-will-hit-south-africa](http://businessstech.co.za/news/finance/563176/how-russias-invasion-of-ukraine-will-hit-south-africa).
- Comins, Lyse. "South Africans Should Not "Take Sides" in Ukraine Invasion, DIRCO Tells Parliament." *The Mail & Guardian*, 16 Mar. 2022, [mg.co.za/top-six/2022-03-16-south-africans-should-not-take-sides-in-ukraine-invasion-dirco-tells-parliament/#:~:text=South%20Africa%20has%20taken%20a%20China-like%20stance%20of](http://mg.co.za/top-six/2022-03-16-south-africans-should-not-take-sides-in-ukraine-invasion-dirco-tells-parliament/#:~:text=South%20Africa%20has%20taken%20a%20China-like%20stance%20of).
- Davis, Rebecca. "WAR in EUROPE EXPLAINER: Untangling the Narrative Web Surrounding South Africa's Stance on the Russia-Ukraine Conflict." *Daily Maverick*, 7 Mar. 2022, [www.dailymaverick.co.za/article/2022-03-08-untangling-the-narrative-web-surrounding-south-africas-stance-on-the-russia-ukraine-conflict/](http://www.dailymaverick.co.za/article/2022-03-08-untangling-the-narrative-web-surrounding-south-africas-stance-on-the-russia-ukraine-conflict/).
- Duho, King Carl Tornam, et al. *Exploring the Russo-Ukrainian crisis and its impact on African countries: a cross-regional analysis*. SSRN, 2022.
- Fabricius, Peter. "COMRADES in ARMS: Russia Welcomes "Friendly State" SA's Support – but Do We Also Support Invasion, Bombardment and War Crimes in Ukraine?" *Daily Maverick*, 17 Aug. 2022, [www.dailymaverick.co.za/article/2022-08-17-russia-welcomes-friendly-state-sas-support-but-do-we-also-support-invasion-bombardment-and-war-crimes-in-ukraine/](http://www.dailymaverick.co.za/article/2022-08-17-russia-welcomes-friendly-state-sas-support-but-do-we-also-support-invasion-bombardment-and-war-crimes-in-ukraine/).
- Fabricius, Peter. "SA Abstains on a UN General Assembly Resolution Condemning Russia... Again." *Daily Maverick*, 12 Oct. 2022,

[www.dailymaverick.co.za/article/2022-10-13-sa-abstains-on-a-un-general-assembly-resolution-condemning-russia-again/](http://www.dailymaverick.co.za/article/2022-10-13-sa-abstains-on-a-un-general-assembly-resolution-condemning-russia-again/).

Fabricius, Peter. "WAR in EUROPE: Pretoria Scrambles to Repair Relations with Russia after Calling for Invasion Forces to Leave Ukraine." Daily Maverick, 27 Feb. 2022, [www.dailymaverick.co.za/article/2022-02-27-pretoria-scrambles-to-repair-relations-with-russia-after-calling-for-invasion-force-to-leave-ukraine](http://www.dailymaverick.co.za/article/2022-02-27-pretoria-scrambles-to-repair-relations-with-russia-after-calling-for-invasion-force-to-leave-ukraine).

García, Gilberto. "The Observatory of Economic Complexity | OEC." OEC - the Observatory of Economic Complexity, oec.world/en.

Gottschalk, Keith. "History May Explain South Africa's Refusal to Condemn Russia's Invasion of Ukraine." The Conversation, [theconversation.com/history-may-explain-south-africas-refusal-to-condemn-russias-invasion-of-ukraine-178657#:~:text=The%20South%20African%20government%20has%20explained%20that%20it,did%20not%20foreground%20the%20call%20for%20meaningful%20engagemen](https://theconversation.com/history-may-explain-south-africas-refusal-to-condemn-russias-invasion-of-ukraine-178657#:~:text=The%20South%20African%20government%20has%20explained%20that%20it,did%20not%20foreground%20the%20call%20for%20meaningful%20engagemen).

Gramer, Robbie. "Inside the Desperate Diplomatic Efforts to Salvage U.S.-South Africa Ties." Foreign Policy, 19 July 2023, [foreignpolicy.com/2023/07/19/south-africa-russia-putin-ukraine-war-global-south-agoa-biden-diplomacy/](https://foreignpolicy.com/2023/07/19/south-africa-russia-putin-ukraine-war-global-south-agoa-biden-diplomacy/).

Mohamed, Hamza. "Why South Africa Continues to Be Neutral in Ukraine-Russia War." Russia-Ukraine War News | Al Jazeera, 24 Jan. 2023, [www.aljazeera.com/news/2023/1/24/why-is-south-africa-neutral-in-ukraine-russia-war](http://www.aljazeera.com/news/2023/1/24/why-is-south-africa-neutral-in-ukraine-russia-war).

Nathan, Laurie. "Russia's War in Ukraine: How South Africa Blew Its Chance as a Credible Mediator." The Conversation, [theconversation.com/russias-war-in-ukraine-how-south-africa-blew-its-chance-as-a-credible-mediator-181101](https://theconversation.com/russias-war-in-ukraine-how-south-africa-blew-its-chance-as-a-credible-mediator-181101).

O'Regan, Victoria. "Mystery Russian Ship Leaves Simon's Town, Still No Official Explanation." Daily Maverick, 9 Dec. 2022, [www.dailymaverick.co.za/article/2022-12-09-mystery-russian-ship-leaves-simons-town-still-no-official-explanation/](http://www.dailymaverick.co.za/article/2022-12-09-mystery-russian-ship-leaves-simons-town-still-no-official-explanation/).

McKaiser Eusebius, Polakow-Suransky, Sasha. "South Africa's Self-Defeating Silence on Ukraine." Foreign Policy, [foreignpolicy.com/2022/03/18/south-africa-ukraine-russia-putin-ramaphosa-war-diplomacy-negotiation/](https://foreignpolicy.com/2022/03/18/south-africa-ukraine-russia-putin-ramaphosa-war-diplomacy-negotiation/).

Seekings, Jeremy, and Chris Saunders. "The Russian Invasion of Ukraine and the Future of Democracy in South Africa." The Strategic Review for Southern Africa 44.1 (2022).

Sihlobo, Wandile. "How South African agriculture – and consumers – will feel the war in Ukraine." Econ3x3, 9 March 2022, [www.econ3x3.org/article/how-south-african-agriculture-and-consumers-will-feel-war-ukraine](http://www.econ3x3.org/article/how-south-african-agriculture-and-consumers-will-feel-war-ukraine).

- “South Africa–Ukraine Relations.” Wikipedia, 4 Nov. 2022,  
[en.wikipedia.org/wiki/South\\_Africa%E2%80%93Ukraine\\_relations](https://en.wikipedia.org/wiki/South_Africa%E2%80%93Ukraine_relations).
- Stark, Vicky. “South Africa Criticized for Abstaining on UN Ukraine Resolution.” VOA, 3 Mar. 2022,  
[www.voanews.com/a/south-africa-criticized-for-abstaining-on-un-ukraine-resolution/6468748.html](https://www.voanews.com/a/south-africa-criticized-for-abstaining-on-un-ukraine-resolution/6468748.html).
- Stoddard, Ed. “FUEL and INFLATION: South Africa’s Retail Petrol Price Set to Hit a Record of R21.60 a Litre.” Daily Maverick, 27 Feb. 2022,  
[www.dailymaverick.co.za/article/2022-02-27-south-africas-retail-petrol-price-set-to-hit-a-record-of-r21-60-a-litre/](https://www.dailymaverick.co.za/article/2022-02-27-south-africas-retail-petrol-price-set-to-hit-a-record-of-r21-60-a-litre/).
- Thamm, Marianne. “How South Africans Thwarted Secret Putin/Zuma Nuclear Deal.” Daily Maverick, 18 Dec. 2019,  
[www.dailymaverick.co.za/article/2019-12-19-how-south-africans-thwarted-secret-putin-zuma-nuclear-deal/](https://www.dailymaverick.co.za/article/2019-12-19-how-south-africans-thwarted-secret-putin-zuma-nuclear-deal/).
- The Moscow Times. “Moscow Expels Estonian Ambassador as Tallinn Pledges More Arms to Kyiv.” The Moscow Times, 23 Jan. 2023,  
[www.themoscowtimes.com/2023/01/23/moscow-expels-estonian-ambassador-as-tallinn-pledges-more-arms-to-kyiv-a80013](https://www.themoscowtimes.com/2023/01/23/moscow-expels-estonian-ambassador-as-tallinn-pledges-more-arms-to-kyiv-a80013).
- “The Union of Soviet Socialist Republics (USSR) and the Anti-Apartheid Struggle | South African History Online.” Wwww.sahistory.org.za,  
[www.sahistory.org.za/article/union-soviet-socialist-republics-ussr-and-anti-apartheid-struggle](https://www.sahistory.org.za/article/union-soviet-socialist-republics-ussr-and-anti-apartheid-struggle).
- Weiss, Andrew S, and Eugene Rumer. “Nuclear Enrichment: Russia’s Ill-Fated Influence Campaign in South Africa.” Carnegie Endowment for International Peace, 2019,  
[carnegieendowment.org/2019/12/16/nuclear-enrichment-russia-s-ill-fated-influence-campaign-in-south-africa-pub-80597](https://carnegieendowment.org/2019/12/16/nuclear-enrichment-russia-s-ill-fated-influence-campaign-in-south-africa-pub-80597).

# EEG Prediction of Psychiatric Disorders By Naina Khurana

## Abstract

Psychiatric disorders pose a significant challenge to individual well-being and society, necessitating innovative diagnostic and treatment approaches. This study explores the potential of electroencephalography (EEG) to uncover neural markers associated with different psychiatric disorders. We conducted EEG assessments on 945 participants, including individuals with various psychiatric disorders and a healthy control group. We analyze EEG data using both logistic regression and a random forest model to identify associations between brainwave frequencies and psychiatric disorders.

These findings reveal distinct EEG patterns across psychiatric disorders, shedding light on potential neural mechanisms. Notably, theta and alpha frequencies display negative associations with certain disorders, while beta frequencies exhibit variations. The random forest model demonstrates promising accuracy in differentiating trauma and stress-related disorder and schizophrenia, though it has lower performance for anxiety disorder.

These results emphasize the importance of considering broader neural dynamics in psychiatric diagnosis and hint at the potential of EEG-based biomarkers. However, further research is needed to refine diagnostic approaches and account for symptom comorbidities in psychiatric disorders. Ultimately, this study contributes to our understanding of the neural underpinnings of psychiatric conditions and opens avenues for improved diagnosis and treatment strategies.

## Introduction

Psychiatric disorders have a significant impact on an individual's cognitive functions, emotions, and behavior, disrupting their overall well-being. These disorders extend beyond causing emotional distress, encompassing tangible consequences such as impaired functionality and societal burdens. The potential for long-term disability, suffering, and even mortality underscores the critical necessity of comprehensively understanding these conditions. Exploring psychiatric disorders goes beyond academic interest, assuming a pivotal role in ensuring the overall health and welfare of individuals [4]. The prevalence of psychiatric disorders is on the rise, as it is estimated that more than one in five U.S. adults live with a mental illness (57.8 million in 2021) [5]. However, existing diagnostic methods often lack the accuracy and timeliness required for effective interventions. This glaring disparity between affliction and adequate care underscores the urgent need for innovative and refined diagnostic approaches.

Electroencephalography (EEG), a non-invasive neuroimaging technique, records the brain's electrical activity through electrodes placed on the scalp. This method offers a real-time window into the dynamic functioning of the brain, capturing synchronized neuronal firing [2]. EEG's significance lies in its capacity to elucidate the temporal dynamics of brain activity, unveiling changes in neural oscillations and connectivity patterns that underlie various cognitive processes and emotional states. These oscillations are categorized into frequency bands, such as

alpha (8-13 Hz), beta (14-30 Hz), and gamma (30-100 Hz), each associated with distinct mental states and functions [3]. For example, alpha waves signify relaxed wakefulness, beta waves indicate active thought and concentration, and gamma waves are tied to cognitive processing and attention.

Yet, a significant challenge persists: the comprehensive characterization of these frequency bands across various psychiatric disorders remains limited. Insight into how conditions like depression, schizophrenia, bipolar disorder, and anxiety disorders affect EEG frequency bands remains incomplete. This knowledge gap obstructs our ability to uncover the neural mechanisms underpinning these disorders, potentially hindering progress in diagnosis and treatment development. Nevertheless, EEG data holds immense potential to reveal the hidden neural mechanisms of these disorders, offering valuable insights into diagnosis and treatment strategies

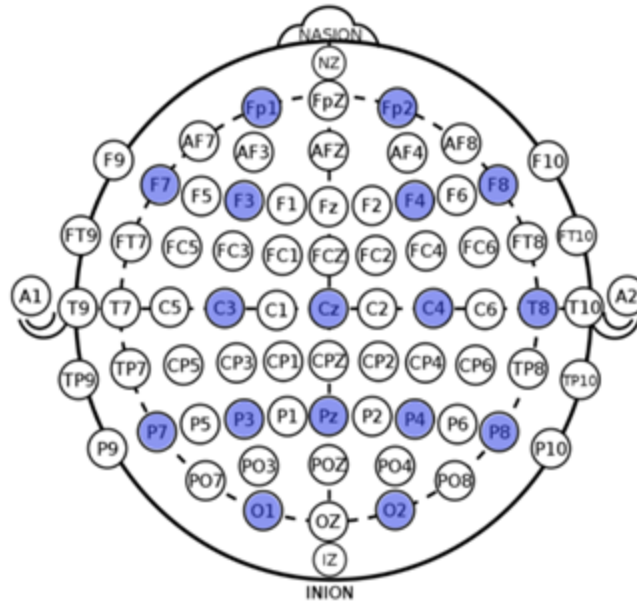
This study aims to identify EEG features associated with different psychiatric disorders using a publicly available dataset containing approximately 1k participants[1]. The goals of this project include: firstly, identifying prevalent result patterns and uncovering both commonalities and disparities in spectral trends among various brain disorders; secondly, presenting the dependability and uniformity of outcomes across different disorder categories, in order to ascertain the legitimacy of employing power spectral analyses for insights into individual psychiatric conditions. By analyzing differences in frequency and power levels across different groups, I hope to provide a deeper understanding of the neural mechanisms underlying these disorders and ultimately improve patient outcomes.

### **Materials and Methods– Experimental Subjects**

This study used available EEG data of 945 participants who were diagnosed with various psychiatric disorders, and 95 healthy controls. Participants were ages 18-70 and their primary diagnoses fell within six major categories of psychiatric disorders: schizophrenia, mood disorders (depressive disorder and bipolar disorders), anxiety disorders (panic disorder and social anxiety disorders), obsessive-compulsive disorder, addictive disorders (alcohol use disorder and behavioral addiction), and trauma and stress-related disorders (PTSD, acute stress disorder, and adjustment disorder).

### **EEG Settings and Parameters**

During the resting-state assessment, EEG data was recorded for a 5-minute period using either a 19-channel or 64-channel configuration. The EEG data was acquired using the Neuroscan system (Scan 4.5; Compumedics NeuroScan, Victoria, Australia) with a sampling rate of 500-1,000 Hz and online filters ranging from 0.1 to 100 Hz [1]. A subset of 19 channels was selected based on the international 10–20 system, which is a standard electrode placement system in EEG research. The selected channels are showcased in Figure 1.



**Figure 1.** Selection of EEG Channels for Comprehensive Brain Activity Assessment. Image from Wikipedia

The continuous EEG data was subjected to a fast Fourier transformation (FFT) using the following parameters: epoch duration of 2 seconds, sample rate of 128 samples (256 digital time points), frequency range from 0.5 to 40 Hz, and a resolution of 0.5 Hz with a cosine taper window to minimize leakage. To reduce noise, a minimum length of 60 seconds of EEG data was used for analysis. Power spectral density (PSD) and functional connectivity (FC) were included as EEG parameters for analysis. PSD represents the spectral power measured at the sensor level and was calculated within specific frequency bands: delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–25 Hz), high beta (25–30 Hz), and gamma (30–40 Hz) [1]. FC, measured as coherence values, indicates the synchronization between two signals based on phase consistency.

### Classification of Psychiatric Disorders

When considering the classification of psychiatric disorders, I evaluated two machine learning (ML) methods: random forest (RF) and logistic regression.

#### *RF Model:*

In my study, I employed a random forest model as an alternative classification technique to distinguish between various psychiatric disorders based on EEG features. Utilizing the sklearn python package to build RF model, I construct the random forest model by combining 300 decision trees and setting a maximum depth of 5. This approach aims to prevent overfitting and ensure reproducibility. I trained the model using testing data (80% training, 20% testing split), and used this to predict on unseen (I.e., testing) data. I used feature importance analysis to identify the most influential EEG features for classification of psychiatric disorders using the RF model.



*Logistic Regression Model:*

In my research study, I chose to employ a logistic regression model to investigate the relationship between EEG features and psychiatric disorders. Logistic regression will allow me to correlate frequency bands with different psychiatric disorders. To create and fit the logistic regression models, I utilize the statsmodels. Logit class from the statsmodels library. I trained the logistic regression model using the training dataset, which consisted of EEG data and corresponding labels indicating the presence of different psychiatric disorders. Leveraging the logistic regression approach, I estimated the beta coefficient between frequency bands and psychiatric disorders. These estimates allowed me to identify the EEG features that may have significant associations with specific psychiatric disorders. I then assessed the results of my logistic regression model and generated model summaries to deepen my understanding of the relationship between EEG features and psychiatric disorders.

**Results**

**Table 1.** Summary of Alpha and Beta Values by Main Disorder

<b>Disorder</b>	<b>Alpha Mean</b>	<b>Beta Mean</b>	<b>Mean Age</b>
Healthy control	21.111	9.961	25.7
Addictive disorder	23.441	11.092	29.6
Anxiety disorder	21.972	12.295	29.0
Mood disorder	24.839	13.340	30.9
Obsessive compulsive disorder	25.285	10.632	28.5
Schizophrenia	27.115	14.177	31.7
Trauma and stress related disorder	27.938	32.341	36.1
Average	24.529	12.301	30.2

Notes: the table presents the mean values of alpha and beta frequencies for each main disorder, along with the mean age of participants

The table below presents the mean alpha and beta frequencies among participants with various psychiatric disorders. The data shows that participants diagnosed with schizophrenia and trauma and stress-related disorders have the highest mean alpha frequencies, recorded at 27.115 Hz and 27.938 Hz, respectively. Conversely, healthy controls and individuals with anxiety disorders exhibit lower mean alpha values, at 21.111 Hz and 21.972 Hz, respectively. In mean beta frequencies, the trauma and stress-related disorder group stands out with the highest value at 32.341 Hz, followed by participants with mood disorders, who display a relatively higher mean beta frequency at 13.340 Hz. In contrast, healthy controls demonstrate the lowest mean beta frequency, recorded at 9.961 Hz. These findings suggest significant variations in EEG patterns

across different psychiatric disorders, highlighting the potential relevance of EEG analysis in understanding neural dynamics in these clinical populations.

**Table 2.** Logistic Regression Coefficients of Brainwave Frequency Bands in Psychiatric Disorders and Healthy Controls

<b>Psychiatric Disorder</b>	<b>theta</b>	<b>alpha</b>	<b>beta</b>
Healthy control	0.13	0.16	-1.06***
Addictive disorder	0.12	0.16	-0.66***
Anxiety disorder	-0.11***	-0.26***	0.68
Mood disorder	-0.24***	-0.24***	0.89
Obsessive compulsive disorder	0.12	0.71	-2.35***
Schizophrenia	-0.38***	-0.21***	1.18
Trauma and stress related disorder	0.24	-0.22***	0.7

Notes: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Table 2 displays the logistic regression coefficients for brainwave frequency bands across different psychiatric disorders and the healthy control group. Theta activity exhibits negative coefficients for anxiety disorder, mood disorder, and schizophrenia, suggesting a negative association between theta frequency and these groups. Alpha activity has negative coefficients for anxiety disorder and mood disorder, while obsessive-compulsive disorder has a positive coefficient, indicating increased likelihood with higher alpha activity.

In the beta frequency band, healthy controls, individuals with addictive disorders, and those with anxiety disorders exhibit negative coefficients, indicating an inverse relationship between beta activity and their conditions. In contrast, schizophrenia and trauma-related disorders have positive coefficients, suggesting a direct link between higher beta activity and membership in these groups. This reveals that groups with negative coefficients tend to have lower power in beta frequencies. Therefore, higher beta activity reduces the likelihood of belonging to the former groups and increases the likelihood of being in the latter groups.

**Table 3.** ROC AUC Scores for Different Psychiatric Disorders

<b>Psychiatric Disorder</b>	<b>ROC AUC Score</b>
Addictive disorder	0.554
Anxiety disorder	0.480
Mood disorder	0.566
Obsessive compulsive disorder	0.589
Schizophrenia	0.623

Trauma and stress related disorder

0.696

Notes: ROC AUC scores indicate the accuracy of the Random Forest classifier in distinguishing psychiatric disorders based on EEG features.

Table 3 provides a crucial insight into the performance of the random forest classification model in distinguishing between different psychiatric disorders. The Receiver Operating Characteristic Area Under the Curve (ROC AUC) scores serve as indicators of the model's ability to accurately classify these disorders. Notably, trauma and stress-related disorder exhibits the highest ROC AUC score of 0.696, suggesting a strong discriminatory capability of the model for this condition. Schizophrenia follows closely with an ROC AUC score of 0.623, indicating a noteworthy accuracy in classification. In contrast, anxiety disorder presents a lower ROC AUC score of 0.480, implying a comparatively reduced accuracy in differentiation using the selected EEG features.

## Discussion

The results showcase average alpha and beta frequencies across psychiatric disorders. Healthy controls typically have lower alpha and beta values, 21.1 and 9.9, respectively, while other disorders vary more widely, with alpha ranging from about 21.9 to 27.9 and beta from approximately 10.6 to 32.3. On average across all disorders, alpha and beta values center around 24.5 and 12.3, respectively. Significant associations were found between brainwave frequencies and psychiatric disorders (Table 2). Specifically, lower power in theta and alpha frequencies correlated with several psychiatric disorders. Negative theta coefficients were linked to anxiety, mood, and schizophrenia, while alpha coefficients were negatively associated with anxiety and mood disorders and positively associated with obsessive-compulsive disorder. In the beta frequency range, healthy controls showed significantly lower beta power compared to all other groups. Negative beta coefficients were associated with healthy controls, addiction, and anxiety, while positive beta coefficients were potentially linked to schizophrenia and trauma-stress disorder. Table 3 highlights the Random Forest's efficacy, notably in distinguishing trauma-stress disorder (ROC AUC 0.696) and schizophrenia (ROC AUC 0.623), with lower accuracy for anxiety disorder (ROC AUC 0.480). These findings set the stage for our discussion on their implications.

The logistic regression analysis uncovers distinct EEG feature patterns across psychiatric disorders. Negative coefficients for theta activity in anxiety disorder, mood disorder, and schizophrenia indicate variations in neural synchronization, may potentially linked to disrupted cognitive and attentional processes unique to each disorder[6]. Moreover, the positive alpha coefficient in obsessive-compulsive disorder sheds light on alpha oscillations' discriminatory role, suggesting potential involvement in inhibitory mechanisms or underlying the disorder's symptomatology [7]. Within the beta band, negative coefficients for healthy controls and specific disorders imply beta oscillations' contribution to sensorimotor integration and cognitive control.

Conversely, positive coefficients for schizophrenia and trauma and stress-related disorder hint at a more intricate role, possibly involving dysregulations or compensatory mechanisms. Across different psychiatric disorders, I observed a U-shaped pattern in beta frequency values. Healthy controls exhibit relatively low beta values, typically around -1. In contrast, individuals with obsessive-compulsive disorder (OCD) stand out with notably low beta values, around -2, while others were not statistically significant (slightly positive). This inverted U-shaped distribution signifies that beta frequency patterns that lie somewhere in between may be most associated with healthy control, while abnormally high or low may be more likely to be associated with the other disorders.

The RF model's ability to consider numerous decision trees collectively enhances its robustness and predictive capacity. The results demonstrate that the RF model is promising in differentiating individuals with trauma and stress-related disorder and schizophrenia from other groups. The highest ROC AUC score observed for trauma and stress-related disorder suggests a substantial discriminatory capability of the model for this specific condition. The noteworthy accuracy in classifying schizophrenia further emphasizes the potential of EEG features in capturing the nuances of this complex disorder. In a related study by Park et al. (2021), which employed a machine learning approach on resting-state EEG data, similar observations were made regarding the discrimination of psychiatric disorders. Park et al. found varying degrees of accuracy for different psychiatric disorders, with schizophrenia exhibiting the highest accuracy. They also noted that accuracy improved when classifying specific diagnoses, such as PTSD, as opposed to grouping disorders into larger categories. These findings align with our own observations, suggesting that EEG-based prediction models have the potential to provide valuable insights into the classification of psychiatric disorders. However, the comparatively lower ROC AUC score for anxiety disorder indicates that while the model's performance is promising, there might be additional factors beyond EEG features influencing the classification accuracy for this disorder.

The strengths of this study lie in its comprehensive exploration of EEG features across a range of psychiatric disorders and its utilization of both logistic regression and Random Forest classification techniques. The inclusion of a healthy control group and a diverse sample of individuals with various psychiatric conditions enhances the robustness and generalizability of the findings. In conclusion, this study of alpha and beta frequencies highlights the unique brainwave patterns in psychiatric disorders. This emphasizes the need for a comprehensive diagnostic approach that considers broader neural dynamics.

## **Limitations**

Several limitations should be acknowledged. The study focused solely on resting-state EEG data, which may not capture dynamic changes in brain activity that occur during specific cognitive tasks or emotional states. The cross-sectional nature of the data limits our ability to establish causality or infer temporal relationships between EEG features and psychiatric disorders. Additionally, the study's reliance on specific EEG frequency bands may overlook the

potential contributions of other frequency ranges to psychiatric conditions. However, this is a large dataset of different psychiatric disorders, and thus xxx. In future work, I will do. Future research should expand on this work by using predictions with a cognitive task.

The generally common pattern across multiple disorders is an indication that individual frequency bands or even a pattern across frequency bands does not serve as a useful measure of distinction between disorders. It also strongly makes the case that studying individual disorders in isolation can be very misleading. For instance, a higher theta/beta ratio is considered an indicator of ADHD in children and even approved as a diagnostic marker by the FDA<sup>8</sup>. However, a similarly higher theta/beta ratio would be likely for schizophrenia and OCD as well. Psychiatric disorders are generally a loose set of symptoms that may overlap across disorders and there may be additional symptom comorbidities that are not accounted for in studies. Consequently, analysis based on specific symptoms and symptom clusters may yield more specific insights. This is particularly important to consider in the context of biomarkers based on the power spectrum.

### Works Cited

- [1] Park, S.M., Jeong, B., Oh, D.Y., Choi, C.-H., Jung, H.Y., Lee, J.-Y., Lee, D., & Choi, J.-S. (2021). "Identification of Major Psychiatric Disorders From Resting-State Electroencephalography Using a Machine Learning Approach. *Frontiers in Psychiatry*, 12." <https://doi.org/10.3389/fpsy.2021.707581>.
- [2] Biasiucci, A., Franceschiello, B., & Murray, M. M. (2019). Electroencephalography. *Current biology : CB*, 29(3), R80–R85. <https://doi.org/10.1016/j.cub.2018.11.052>
- [3] Marzbani, H., Marateb, H. R., & Mansourian, M. (2016). Neurofeedback: A Comprehensive Review on System Design, Methodology and Clinical Applications. *Basic and clinical neuroscience*, 7(2), 143–158. <https://doi.org/10.15412/J.BCN.03070208>
- [4] Stuart H. (2016). Reducing the stigma of mental illness. *Global mental health (Cambridge, England)*, 3, e17. <https://doi.org/10.1017/gmh.2016.11>
- [5] U.S. Department of Health and Human Services. (2023, March). *Mental illness*. National Institute of Mental Health. [https://www.nimh.nih.gov/health/statistics/mental-illness#part\\_2541](https://www.nimh.nih.gov/health/statistics/mental-illness#part_2541)
- [6] Maresh, E. L., Stim, J. J., Van Voorhis, A. C., Kang, S. S., Luciana, M., Sponheim, S. R., & Urošević, S. (2019). Neurophysiological correlates of cognitive control and approach motivation abnormalities in adolescent bipolar disorders. *Cognitive, affective & behavioral neuroscience*, 19(3), 677–691. <https://doi.org/10.3758/s13415-019-00719-x>
- [7] Ciesielski, K. T., Hämäläinen, M. S., Geller, D. A., Wilhelm, S., Goldsmith, T. E., & Ahlfors, S. P. (2007). Dissociation between MEG alpha modulation and performance accuracy on visual working memory task in obsessive compulsive disorder. *Human brain mapping*, 28(12), 1401–1414. <https://doi.org/10.1002/hbm.20365>

## The Fall of Ming: An Investigation of a Rapid Shock on the Chinese Identity By Edmond Meng

### Abstract

Seldom captivates the human mind much as the imagination of a bygone time. In the old English poem titled *The Ruin*, the unknown author marveled at the Roman ruins, referring to them as “the decaying works of giants”(see Klink 2001: 12-16)<sup>59</sup>. Even educated medieval scholars, well-versed in the Roman Empire’s history and its continuation in Anatolia, could not help but wonder about the apocalyptic fall of Rome. In the Far East, a similar romanticization manifests itself in the transition from the Ming to the Qing dynasty.

The Ming Dynasty, with its foundational legitimacy rooted in fending off the Northern Barbarians, sealed its fate in 1644 when Wu Sangui surrendered the Shanhai Pass to the Manchu Bannerman<sup>60</sup>. This surrender initiated a century of relentless warfare that ravaged every part of China. The Manchus, after settling in Beijing, set out to pacify the remnants of the Ming dynasty in the rump state of Southern Ming, marking the beginning of a protracted conquest with entire cities exterminated. Yet this was merely the second wave of calamities that deconstructed Chinese societies during the 1600s. Since the turn of the century, China had grappled with a series of severe droughts, famines, plagues, and rebellions, leading to a drastic estimated forty percent decline in its population.<sup>61</sup> Shockwaves also reverberated culturally, as the conquest ushered in a period of profound cultural upheaval, where, for instance, Chinese men were forced to shave their hair and disobey and abandon traditional Confucian clothing etiquette.

In more recent memory, on February 15th, 1912, Sun Yat-Sen, newly appointed as the President of the Republic of China, made a significant official visit to the Xiaoling (Ming) Mausoleum with a massive entourage. This visit symbolized the burgeoning racial animosity against the Qing regime and an intensifying veneration for the Ming dynasty:

“Only the Taizu (Ming’s founder), who rose up from the peoples, was able to exterminate evil, and restore the orthodoxy. In only 12 years, he accomplished the great enterprise... But his posterity was useless, and did not inherit his brilliance and martiality. They let villains assume governance, and allowed the eastern barbarians to grow in strength. Those same barbarians, taking advantage of the rebellions, occupied the holy capital. They controlled China with menace, tainted the land, and placed our people to the sword...”<sup>62</sup>

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<sup>59</sup> The poem ‘The Ruin’ is an Old English elegy, believed to have been composed by an anonymous author in the 8th or 9th century. It was later published in the 10th century within the Exeter Book, an extensive compilation of poems and riddles (see Klink 2001: 12-16). The verses vividly portray the faded splendor of an unnamed, ancient city in ruins. Some scholars have linked this city to modern Bath, contrasting its once magnificent and vibrant history with its current state of decay

<sup>60</sup> Wakeman(1985), *The Great Enterprise*, 305-308

<sup>61</sup> Wakeman, *China and the seventh-century crisis*, pg. 1-6

<sup>62</sup> Hsiu Shishen(1967), *The Records of the Founding Father Sun Zhongshan as the Temporary President*, pg. 264-265,

The transition period began to be analogized with the Fall of Rome, where a civilized world was dismantled by a barbaric power. Sun Yat-Sen likened his revolutionary enterprise, which overthrew the Qing, to that of Zhu Yuanzhang's conquest of the Yuan (Mongols). Nationalism was a powerful tool in the Earlier Chinese Revolution, and that did not stem from nothing.

During the transition, the Ming was not venerated nor revered during as much as it is today. Similar to the collapse of the Western Roman Empire, the fall of the Ming dynasty was a slow and painful process. However, the sudden Qing crossing of the Shan-Hai Pass was a shock that made the conflict just so much more different. Dorgon, the de-facto ruler and prince regent of Qing, embarked on the conquest under a supposed righteous cause<sup>63</sup>: to avenge the Ming and punish Li<sup>64</sup>. Believing the universality and popularity of the new Qing regime, the Manchu power was confident to take on the conquest. In reality, the Qing found themselves to be in hostile foreign lands. Instead of the swift and surgical war, the transition period was a drawn-out process that brought ethnicities into question. The Qing regime was frustrated by the stubborn resistances in the South, and subsequent rebellions by surrendered Han generals. Dorgon's intention for inclusivity of the Chinese by requiring everyone to adopt the Manchu hairstyle dislodged the momentum of Qing conquest. It became an ethnic/cultural carnage that Dorgon and the Qing had not anticipated. Throughout the Qing dynasty, the court in Beijing had to deal with consistent Ming-loyalist or Han identity based rebellions in the South. The sharp divide between the ruling regime and its core inhabitants created the perfect environment for identity formation. As the beginning of a new age, the Ming-Qing transition period sheds light on the variety of perspectives on Han identity in the face of a foreign invader. Moreover, it is a time that helps us investigate the nature of ethnic or Han identity prior to the modern age.

Ma Maocai's memorial on Shaanxi

“The servant(himself) comes from Yanan Fu(prefecture). Since last year there has been no rain, causing the vegetation to shrivel. In the eighth and the ninth month, the folks began to collect weeds from the mountains. The weeds were bitter and inedible, but eating them can delay their death. After the tenth month, when all the weeds were eaten, the folks began eating the tree barks. Amongst all the trees, Elm barks tasted a little better. Folks can eat other barks too, but it is only delaying their deaths.”<sup>65</sup>

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<sup>63</sup> Wakeman, *The Great Enterprise*, pg, 306-308. The “righteous cause” was a collaborative effort between Feng Wenchang, a surrendered Chinese official, and Dorgon. Both of them very much believed that the Han Chinese were willing to submit to the Qing cause out of their hate for Li Zicheng's rebellion

<sup>64</sup> Li Zicheng's rebellion is primarily responsible for the destruction of the Ming dynasty

<sup>65</sup> Ji Liuqi, *Mingji Beilue*, 明季北略, was an extensive accounts of Northern China in the late ming and early qing histories in the 17th century. The book itself was banned during the Qing dynasty. It resurfaced in the Republican Era, and subsequently published. The author compiled his personal experiences to write the history. It is considered as a counter



In the early 17th century, the Shanxi region suffered a series of terrible famines. Under the directions of Emperor Chongzhen, Ma Maocai was sent to Shanxi to investigate the rumors of a famine. It was said that families began selling each other into slavery, and ate rocks to satisfy themselves. Ma conducted careful inquiries, documenting the scenes and instances which he saw and heard. The excerpts included within this passage are parts of his entire memorial sent to the Chongzhen emperor.

“Near the end of the year, when all tree bark supplies had gone dry, the folks began digging rocks in the mountain to eat. The rocks were cold, and fishy. Although a small amount could make one satisfied, a few days later the person will die due to an imploded stomach.”

It was not long until a great deal of people were forced into banditry. Those people who did not want to perish by eating rocks became highwaymen. The local magistrates soon lost control of the situation. Babies were discarded near city gates daily. Some of them still have the strength to cry for their parents, while some just tried to dig into excrement pits, looking for food. Cannibalism became a common phenomenon. Little children, or just a person who went out of the city alone will magically disappear without a cause. It is likely that they were snatched and made into meals. People outside of the cities will use human bones as firewood, and flesh for consumption. But soon after eating they all die of a strong fever.<sup>66</sup>

“The Qin area, Qingyang, Yanan, and all the area north of it suffered the worst famines, yet its banditry is relatively minimal. But for Xi’an, Hangzhong, and anywhere in the South, the issue of banditry is extremely serious.”

The chaos of the Shanxi famine<sup>67</sup> can serve as a backdrop of the end of Ming in the early 17th century. Repeated series of mass hunger, and the breakdown of imperial order pushed many able-bodied peasants into mass rebellions and banditry. Li Zicheng, the man who toppled the Ming, was a Shanxi native, hailing from Yan’an himself. His endless supply of soldiers is secured by the desperate situations in the Shanxi province. In reality, depopulation was a common phenomenon across China. Frequent famines. During the Late Ming, it is estimated that between 1585 and 1645 that the population of China have dropped by about forty percent<sup>68</sup>. It was not long until the Ming government began a systematic collapse. In 1629 the government

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resource to see the official “ming shi”, or Ming dynasty history compiled by the court historian. However, it is not official, meaning it is part of Yeshi, or wild histories. Yet most of the histories match with the official records. The passage was self-translated by the author. *Memorial of the report of the great famine*

<sup>66</sup> Ibid, Mingji Beilue.

<sup>67</sup> Brook, Timothy (2010). *The Troubled Empire: China in the Yuan and Ming Dynasties*. US: The Belknap Press of Harvard University Press. pp. 249–253

<sup>68</sup> Wakeman(1986), *China and the seventh-century crisis*, pg. 6

postal service budget was cut by thirty-percent, enough to gut the agency apart. The result was a predictable collapse of communications, where local officials had to hire mercenaries for relaying messages<sup>69</sup> The growing internal threats from Shanxi ,rebellions in the Southwest by ethnic minorities, and the rise of Manchus in Liaodong, would combine themselves as a problem that made Ming destined to fall. But it was Li that truly toppled the Ming institution, when he besieged Beijing in 1645.

### **The final days of Zhu Youjian<sup>70</sup>**

On April 21, Li Zicheng, and his army set camp at Changping, merely a step away from their ultimate goal: Beijing. Rising from a humble courier, to the most powerful man inside of the Pass<sup>71</sup>, Li's extraordinary rise to power out of the ruins of the Great Ming was on the verge of reaching its zenith. Two days later, on April 23, a profound silence enveloped the Chongzhen court as they stood in the presence of the 'Son of Heaven'<sup>72</sup> confronted with the grim reality of a dynasty seemingly no revival. This somber occasion marked the final formal audience that the Emperor held with his ministers. Soon, the vanguard of the Dashing Army<sup>73</sup> emerged outside the walls of Beijing, inducing fear and apprehension among the populace. Li Zicheng, cautious of the consequences of killing an emperor, dispatched a eunuch to negotiate with Chongzhen. The proposed terms include recognizing Li as a rightful king in his territories, and in return offering assistance to the emperor in quelling other rebellions and defending Liaodong. These terms exceeded the expectations of the Chongzhen Court. Crucially, Chongzhen had contemplated various expedient proposals - such as the aforementioned terms - including the relocation of either the crown prince or the Emperor to the South, seeking support from his ministers for these pivotal decisions. However such attempts were met with vehement opposition, particularly from Guang Shiheng, the supervising secretary of the Ministry of war<sup>74</sup>. Hearing no messages from the emperor, Li's army initiated their assault on the city, enveloping the sky from dawn to dusk, accompanied by thick smoke billowing from the suburbs. Chongzhen walked to the Longevity Hill behind the palace to observe the fires. The night had just begun, but the sky was painted red, and there seemed to be no distinction between day and night. Now back at the palace,

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<sup>69</sup> Ibid, pg. 13

<sup>70</sup> Given name of the Chongzhen Emperor

<sup>71</sup> West of Shanhai Pass, which divides the Liaodong and Ming proper

<sup>72</sup> The son of heaven is a widely agreed upon English version of how the Chinese emperor historically refers to himself.

<sup>73</sup> Dashing Army refers to the Chuang Jun, which literally translates to an Army that is dashing.

<sup>74</sup> Every migration discussion Chongzhen started was repudiated by strong minded officials. When the court was considering moving either the crown prince or the Emperor to the South, the supervising secretary of ministry of War Guang Shiheng vehemently opposed the proposal, and berated the officials that suggested the blasphemy. The Southern Officials were fear stricken by Guang's powerful rhetorics, unable to say a thing. That was not the result of which Chongzhen was seeking. Like Wakemen suggested, he wanted to move south, but he needed the urging of his officials so that the move was not to be seen as expedient. Yet his officials were so frantic of the current crisis that they did not dare to urge his majesty to move South. Similarly, when Chongzhen asked his trusted secretary Wei about the terms of surrender, Wei dared not utter a word. Furious at his behavior, Chongzhen lashed out at the throne, and upon seeing the mental breakdown, Wei quickly excused himself out of the palace hall. Matters of negotiations were not brought up again.

Chongzhen issued the final order to send the princes to the South. But none made their way out of the city. Confronted with impending doom, and accompanied only by a handful of his most trusted advisors, the drunken Chongzhen declared: “Our mind is made up, we are unable to defend the she and ji. All we can do is to die for she ji<sup>75</sup>”. Then the emperor wept with his men. His final moments were filled with sorrow and a deep sense of loss, leading to a tragic and frenzied act of violence within the inner palaces<sup>76</sup>.

#### Liu Shangyou and his stint in Beijing

Liu Shangyou embarked on a journey to Beijing during the winter of 1643 in pursuit of an official appointment<sup>77</sup>. Notably, he had familial ties, possibly through marriage, to Shen Zhifeng who held the position of Supervising Secretary for the Ministry of Rites<sup>78</sup>. Liu’s origins traced back to the prosperous and thriving Jiading County in Jiangnan, a considerable distance from the capital. His arduous route took him along the Grand Canal, and then proceeded on land until it froze in Xingji, at which point he continued overland. The entire journey served as a stark reminder of the perilous conditions prevailing in the region. Indeed, Liu was constantly reminded that he and his traveling group were going through bandit country. Along the way, the landscape was marred by the remnants of a once-prosperous civilization, ruins dotted the several hundred li. surrounding the capital<sup>79</sup>. Liu’s recollections underscored the eerie desolation of the Beijing countryside, devoid of any human presence apart from his own travel companions. This desolation was exacerbated by the rampant lawlessness attributed to roving rebels who held sway over northern China during this tumultuous period. Additionally a prolonged famine had cast a long shadow on the region, intensifying its hardships. Despite the apparent perils, Liu and his entourage successfully reached the capital, arriving safely before the Lunar New Year. It was during this brief sojourn in Beijing that Liu bore witness to the imminent collapse of the Ming dynasty. As March of 1644 approached, rumors circulated that Li Zicheng’s rebel army would soon seize control of the imperial city, a prospect met with exuberant cheers from the residents of Beijing. A contemporary account vividly encapsulates this sentiment:

“The ignorant common people took calamity to be good fortune and rejoiced in disaster, all saying that when Master Li arrived, he would give each poor person five taels. They often seemed to look forward

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<sup>75</sup> Sheji - 社稷 - directly means soil and grain, but it is a term to refer to the state

<sup>76</sup> After several drinks, Chongzhen started a demented rampage through the inner palaces. After drinking several cups of wine, he massacred Consort Yuan. The Empress, knowing the end is near, hung herself at the Kunming Palace. Chongzhen cried bitterly, as he slashed down one of his daughter’s arms. Now deep into the night, the emperor already lost his mind, and enjoyed his last drinks with the trusted chief eunuch. He then put on the eunuch’s costume, and followed several hundred eunuchs attempting to leave the city. But the entourage was stopped by suspecting soldiers who thought they were spies. The Emperor’s identity was then revealed by the Chief Eunuch to prevent a violence exchange. Finally, with all hopes of escaping or living dashed, Chongzhen hung himself at a hill immediately north of the forbidden palace.

<sup>77</sup> Struve(1993), *Voices from the Ming-Qing Cataclysm*, pg. 6

<sup>78</sup> Ibid., pg.6

<sup>79</sup> Ibid., pg.7

to the rebel leader's arrival as they would to a year of good harvests."<sup>80</sup>

They looked to the rebel leader's arrival as they would to a bountiful harvest. According to Liu, Beijing had witnessed half of a year without any newborn, and endured two seasons of terrible pestilence, resulting in a substantial loss of life. The Ming's inability to ameliorate economic conditions drove a significant portion of the populace into a life of banditry and lawlessness. Even within the capital, the court had lost the support of its people. When Li Zicheng's bandit army finally entered the capital, their actions fell far short of the commoners' hopes. Li's first act in the capital was to gather thousands of eunuchs, women, and young children to entertain him and his generals. Shen, Liu's relative, had his home commandeered by bandits. The other former Ming officials faced execution threats if they did not present themselves before the Shun court. Unable to reconcile with these deplorable events, Shen attempted suicide.

"The great affairs of the world have come to this. To recompense my dear ruler, I can only die. A commoner castoff of the Shun rebel court, I am a minister of the Ming." He gave this to his valet and then tried to hang himself. Shen first ordered his valet to prepare the rope, then the valet held on to it, straining until his strength was spent. Not long after the noose had fully tightened and he heard a sound from his master's throat, the valet dropped Shen precipitously to the floor. In about half an hour, however, Shen revived and left the room in a daze."<sup>81</sup>

Li's army was vehemently loathed during their stay in Beijing. Women suffered horrendous violations, and men were forced into labor for the Shun army. The streets turned perilous as Shun soldiers plundered anyone perceived as well-to-do.<sup>82</sup>

"Young children were taken to the bandits' (Shun army) quarters and made into sexual playthings."<sup>83</sup>

Li's time in Beijing soon came to an end when his army suffered a crushing defeat in a battle against the Qing dynasty and Wu Sangui<sup>84</sup>. The retreating bandit army hastily seized any valuables within the city, and set the ablaze before struggling out of Beijing's gates. During Their retreat, the rebels mercilessly killed every non compliant captive official and ordered the rest to

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<sup>80</sup> Ibid., pg. 10

<sup>81</sup> Ibid, pg. 14

<sup>82</sup> Ibid, pg.15

<sup>83</sup> Ibid, pg. 15

<sup>84</sup> Wakeman, The Great Enterprise, pg. 305-308

march with them<sup>85</sup>. This request sent officials scrambling to hide themselves<sup>86</sup> The chaotic retreat led to a long line of stragglers, making them easy prey for vengeful Beijing citizens. They executed rebel leaders by , threw soldiers into burning buildings, and decapitated others.<sup>87</sup> Qing's formidable grand army arrived in force. The citizens least expected the Qing army to assume control of the city. Yet, even in this confusion and chaotic situation, the apprehended Beijing citizens resignedly accepted their new rulers<sup>88</sup>. As the Manchu army gradually entered the city, discipline prevailed.<sup>89</sup> They swiftly restored order, manning the defense stations. Common people could once again visit the markets, reminiscent of days of yore. To assuage and allay the populace's fears, Dorgon and his regime issued multiple proclamations informing the people of the new dynasty and reassuring them that the Manchu soldiers would not massacre Beijing's populace. Finally, the Beijing residents found solace and stability (citation needed - Author, Year, Page). Unlike the past generations of foreign rulers, the Qing was of a novel force. It did not massacre and humiliate the Ming, instead it restored order, repaired the palace, rebuilt the Ming tombs, and placed officials back to work. For the people, it seemed like Qing had claimed the mandate of heaven.<sup>90</sup> Liu and Shen nevertheless remained skeptical of the new regime. Emerging from hiding, Shen implored Liu to escape with him and return to their hometown in Jiading. Liu would later succeed in returning home, after experiencing an entire year of treacherous journey filled with bandits and diseases. What is known of him after the ordeal is very minimal, but his hometown of Jiading, Jiangnan, was massacred three times over the transition period. Beijing residents' quick acceptance of the Qing regime differed greatly from the bitter Southern resistance. They were befuddled by the arrival of a "barbarian" prince. Nevertheless, the residents had no energy to propagate a defense anymore after enduring years of famines and warfare. In comparison, Shen and Liu were hesitant about the Qing, evidenced by their quick evacuation upon hearing that all men in the city would shave their heads. The drastic social and economic inequality produced two different reactions.

### **Shi Kefa, the Minister of war.**

Shi Kefa, a prominent figure during this tumultuous period, found himself confronted by a formidable adversary after the Banner army swiftly advanced through the North – the Qing. Ming remnants were forced to relocate in Nanjing, also known as Ying Tian Fu. Nanjing was a significant city of Nanzhili, an expansive metropolitan region encompassing what is now Anhui, Jiangsu, and Shanghai. The term "Nanzhili" literally translates to the Southern Direct Administrative Area, denoting its status as the secondary capital throughout the Ming dynasty. As the secondary capital, Ying Tian Fu mirrored an identical but less influential set of the administrative setup, encompassing the traditional "Six Ministries" (Ministry of Works, Ministry

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<sup>85</sup> Struve, pg. 16

<sup>86</sup> Ibid, pg. 15

<sup>87</sup> Wakeman, *The Great Enterprise*, pg.314

<sup>88</sup> Struve, pg. 19

<sup>89</sup> Wakeman, *The Great Enterprise*, pg. 318

<sup>90</sup> Ibid, pg. 584

of Ceremonies, Ministry of War, Ministry of Personnel, Ministry of Revenue, and Ministry of Justice)<sup>91</sup>.

When the rebel Li Zicheng took the capital, Shi Ke-fa, then the Minister of War in Nanjing, endeavored to assemble and mobilize an army to relieve the besieged northern capital. While the army was en route across the Yangtze River, Shi received the devastating news of Chongzhen's suicide. This tragedy left Shi overwhelmed with despair – he cried while facing the north, and struck his head against a pillar until blood flowed to his feet<sup>92</sup>. By 1644, the Qing regime had firmly established its foothold in the north<sup>93</sup>. Dorgon, the Prince Regent of Qing, acknowledged the imperative to swiftly crush the Southern Ming if the new dynasty wanted to maintain its dominance and legitimacy. Dorgon extended a message to Shi, aiming to persuade the South into a peaceful surrender.

“Back when I was in Shenyang, I'd already heard about the events in Yanjing (Beijing). The people all praise the minister of war(Shi Kefa). When I entered Shanhai Pass and scattered the rebellious thugs, I was able to come into acquaintances with respected peoples of the capital. I also came to know your brother, who helped me to deliver a most heartfelt message to you. I am not sure if it has arrived to you yet.”<sup>94</sup>

However, despite the initial friendliness, Dorgon swiftly altered his tone accusing the Southern court of its supposed unethical conduct.

“My country's settlement in Yanjing is taken from the efforts of the dashing thugs (referring to the dashing army), not by the Ming Dynasty. Those thugs destroyed Ming tombs, and insulted Ming's former emperors. My country, despite great efforts of warfare, and committing all of our forces, proceeded to avenge those indignities. If one is a true filial son, what shall one do to pay back such favor? Now that the bandits are crushed, we halted our advances, while you folks consolidating yourself in Jiangnan, enjoying the fisher man's gains”<sup>95</sup>

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<sup>91</sup> Ibid, pg. 643-644

<sup>92</sup> Wen Ruilin, *Lost Histories of the Southern Frontier*, 7th scroll. The book was written and compiled by a Kangxi era historian who worked on the official Ming Shi (History of Ming). His inspiration from the book is by another court historian who urged him to compile Southern Ming histories due to its lack of records. Translated by the author of this essay.

<sup>93</sup> The Capital was established in Beijing, and the calendar year was Shunzhi.

<sup>94</sup> The Historical Records of the Qing Ancestors, sixth scroll, the record was a continuously worked project throughout the dynasty.

<sup>95</sup> Ibid, Historical Records of the Qing Ancestors

While the Qing clearly did not perceive itself as part of the “Middle Kingdom”, it nevertheless recognized the importance of maintaining itself as a rightful heir to the “Middle Kingdom”. From the start of their conquest, Dorgon was keen to base his conquest in the name of benevolence and revenge for the Ming emperor<sup>96</sup>. He cites the south’s failure to assist the Qing in defeating Li’s rebel army, aiming to undermine their legitimacy. In a way, this was Dorgon’s allegory for the South’s imprudent decision to not emulate Wu Sangui, who surrendered to the Qing for this very purpose<sup>97</sup>. Moreover, it was a way to judge the Southern Ming under Dorgon’s paradigm: the Ming is lost, and the only thing we can do is revenge, not to create another Ming. As for the Southern court, their main priority at the time was to sue for peace and create a dynamic of southern and northern dynasties, a dynamic that would inevitably clash with Dorgon’s ambitions.

“To suddenly receive your highness’s wonderful letter in these times of busy official work, it’s comparable to that of receiving it from heaven! I have read your message, of which I am able to understand your most sincere feelings. When discussing the issues of the rebels, who very much troubled your highness and your noble country, Shi is most grateful, and ashamed. When your highness accused the Southern officials and its people of selfishly fearing for our own safety and hiding in Jiangnan, and forgetting the enemies of the emperor, I feared that your highness did not know the full truth, so please allow Shi to narrate the details to your noble sovereign. The former emperor was a god fearing man who followed ancestral traditions, worked hard in rule, and loved the people. A lord in the ranks of yao and shun! It was the incapable officials such as me, who failed the nation, and caused the tragedy on March 19th. Kefa(referring to himself) held an important southern position, when I led the northern expedition force, arriving at the banks of the Huai River, I received the news of the late emperor’s death. When I received the message, the world seemed to crumble in front of me. My sadness, and shock, were unbound! Alas! Who could do without a lord? Even if I be decapitated in the street as a public display, to set an example of an incapable official that delayed the rescue of the monarch, the late emperor will not forgive my heaven-shaken crime! When

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<sup>96</sup> Wakeman, *The Great Enterprise*, pg. 308

<sup>97</sup> See footnote 32. Wu Sangui was sandwiched between the attacking Li Zicheng and the Manchu camping outside of Shanghai Pass. Upon hearing the execution of his family in the hands of Li, Wu Sangui sought after the Manchu for support.

both the Southern officials and common folks, when they heard the tragedy, cried out in despair, as if they lost their parents, none was not punching their chests, proclaimed loudly that they shall use all of the SouthEastern armies to eliminate the enemies.”<sup>98</sup>

Most of the court believed that they could negotiate with the Qing, and eliminate the rebels first (citation needed - Author, Year, Page). Throughout the country, dealing with civil rebellions (or in many cases, political opponents) seemed a more pressing issue than actually fighting the Qing<sup>99</sup>. This fragmentation was detrimental to the Southern Ming efforts over the next half-century. As for Shi, he was seen as embodying the role of a devout Confucian scholar-official. However, it was a stretch to say that his determination to defend Ming reflected the people’s will.

“If the noble sovereign takes advantage of our country’s desperate situation; views our dynasty as rump; moves south with the thy army; uses the rebels as vanguards; accuses us in perverted logics; reap the profits; it will surely be an act that confuses the right and wrong; appreciation and hatred. It will only encourage the spirits of the rebels. This act, not only wastes our sincere efforts of borrowing troops from thy noble sovereign, but also betrays your highness’s original intentions: an righteous rescue of our dynasty from crisis... Huihu(Uyghur Khaganate) sent troops to help Tang, and did not ask for any lands... Your noble country has maintained generational friendship with my dynasty. This act of righteous rescue will surely be complimented for tens of thousands of generations. If you take advantage of our crisis, see us as enemies, and take my dynasty’s lands. Not only you cannot accomplish your good deeds, but you will start with righteousness, and end with unearned profits. Wouldn't this act not be mocked by the rebels? Does your noble sovereign truly desire this?”<sup>100</sup>

Throughout the exchange, both Dorgon and Shi used allegories and examples to imply insults or accusations. Shi’s consistent references to the rebels was a way for him to express that the Qing were just as much a thug as Li if the Qing proceeded the way Dorgon desired.

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<sup>98</sup>Dong-Hua-Lu, written and compiled by Jiang Liangqi during his time in the National History Institution(Guo Shi Guang).

<sup>99</sup>The History of Ming - a record compiled and edited by generations of Qing Court historians. “士英厉声叱曰：若辈东林，犹借口防江，欲纵左逆入犯耶？北兵至，犹可议款。左逆至，则若辈高官，我君臣独死耳！”

<sup>100</sup>Jiang Liangqi, Dong-Hua-Lu



“...Kefa looks out for the mausoleum in the north with no more tears to shed. I have committed heavenly-shaken crimes that are deserving to die a thousand times. The only reason that I have not followed my lord to the depths of the underworld is my responsibility to the state. There is a saying: use your all to assist your lord, and be faithful for an eternity. On this day, Kefa, with all his sincerity, respect, and heart, is completing an official duty. Soon I will lead the 3 armies to cross the rivers, destroy the rebels’ hideouts, and restore all of China; In an effort to repay Hongguang and the former’s favors. If your noble country has other advice, I fear that I cannot accommodate to listen. I wish your highness would judge wisely.”  
-Hongguang, year of jiashen(1644), fifteenth day of the ninth month<sup>101</sup>

Shi was likely the only person determined to fight the Qing at any cost. In reality, there were no three armies capable of marching out of the south to destroy the rebels. Shi’s role as the commander in chief of the Northern forces proved to be disastrous. The northern defenses had four key towns, all of them controlled by his rival’s allies, or by semi-renegade generals<sup>102</sup>. Yet, the letter was a clear message to Dorgon that he was to hold the south at all costs. Although Shi only talked about fighting the rebels, it was actually an implication to Dorgon that Shi is ready for a fight with the Qing. It was at this point that Shi accepted Qing’s ambitions, and realized the day-dream of a Ming-Qing alliance was futile. His sharp criticisms of Qing’s hypocrisy reinforced the legitimacy of Southern Ming, an action that will tempt Dorgon’s wrath. After the exchange of letters, Shi tried to consolidate the defense of the Yellow River line by gaining General Gao’s support. Yet, Gao was also the most unruly of the generals. His army acted like bandits, pillaging their way as they marched. The devastation was so bad that the Ming officials lamented:

“When they murder: thousands of bodies piled up in the countryside.  
When they rape: even small girls aren’t spared.”<sup>103</sup>

Such actions were not uncommon. Civil order essentially broke down in the 1630s and 40s. Ming soldiers, who farmed on given lands to self-sustain themselves, often robbed and pillaged surrounding villages. Villages also attacked and robbed the Ming garrisons. When Shi finally established a relatively stable defense, he was recalled to Nanjing to fight off another

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<sup>101</sup> Ibid, Jiang Liangqi

<sup>102</sup> Struve, pg. 28

<sup>103</sup> Jiayishian, cases and instances in Jiayi, the texts are collected by Donald Sturgeon’s wonderful database of Chinese classics. The passage was written by Wen Bing, a descendant of an Eastern Grove factional. He was a staunch Ming loyalist and never submitted to the Qing. His work was compiled independent of the court’s history.

group of renegade armies besieging Nanjing<sup>104</sup>. The recall devastated Shi, as he knew that his sudden departure would collapse the army morale up north<sup>105</sup>. Finally in 1645, Shi was relieved to go back to the northern defense line. Shi wrote his last letters to his family, knowing the impending doom of Yangzhou. In his final letters, Shi tearfully expressed his utmost sorrow at his incompetence. A man with great ambitions, Shi Kefa's destiny met with an unfortunate end with a hopeless situation. He knew that all the chances to win the war had dissipated.

“An unworthy son, Kefa, leaves this missive for his esteemed mother: In eighteen years of official service, I have tasted every bitterness and yet been unable to increase the welfare of the court. I have only been vastly remiss in attending to my parents.<sup>8</sup> Neither effectively loyal nor filial, how can I show my face in the world? Now, even if I die fighting for this city, it will not be sufficient to atone for the wrongs I have done. I hope that Mother will attribute it to fate and not be too sorrowful again. Your son for his part will harbor no hatreds when he lies underground. I have obtained the agreement of my chief military aide, [Shi] Dewei, to finish those matters that should be handled by a son after a father's death, and I hope that Mother will treat him affectionately, like a real grandson.”

*Written tearfully by unworthy Kefa, 4th month, eighth day [May 14, 1645] - STRUVE (citation needed - Author, Year, Page)*

Kefa is about to die. I made a pact with you, my wife,<sup>10</sup> that we would wait for one another in the grave.

*Written personally by Kefa 4th month, 19th day<sup>106</sup>*

Kefa leaves this letter for his esteemed uncle, elder brother, worthy third younger brother, and other brothers and nephews: 'The Yang-zhou city wall will fall within a day and a night. Months of toil and strain have come to this end. How could I resent using my one death to recompense the court? I regret only that the death of our former emperor [Chongzhen] has not been avenged. I have obtained the consent of my chief military aide, Dewei, to take care of affairs after my death. He should be accepted into our lineage in the same generation as my various nephews. Do not go back on this, my word.

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<sup>104</sup>The History of Ming - a record compiled and edited by generations of Qing Court historians. When the renegade General Zuo besieged Nanjing, Ma Shiyong, a highly ranked Ming official blasted his political opponents for allowing Zuo to attack. In the quote, he famously said that: “When the northern troops arrive, we still could negotiate. If the traitor Zuo is here, then all of us die!” “士英厉声叱曰：若辈东林，犹借口防江，欲纵左逆入犯耶？北兵至，犹可议款。左逆至，则若辈高官，我君臣独死耳！”

<sup>105</sup> Struve pg. 28-29

<sup>106</sup> Struve, pg. 30-31

*Written by Kefa in the West Gate Tower of the Yangzhou city wall, 4th month, 19th day<sup>107</sup>*

[To Shi Dewei:] Kefa, who received great favor from our former emperor, has been unable to carry out the ultimate revenge for his death. Even though I received great favor from the present emperor [Hongguang], I have been unable to protect his domain. Even though I received great favor from my kind mother, I have been unable to make filial provision for her. I have run upon unfortunate times, in which my will could not be fulfilled. To repay the nation with this one death is surely my destiny. I only regret not having earlier followed our former emperor to the grave.

*Kefa's last pen stroke, 4th month, 19th day<sup>108</sup>*

“Respectfully wishing [my mother] Madam [Shi], [my mother-in-law] Madam Yang, and my wife boundless peace: The Northern [Qing] troops surrounded the Yangzhou city wall on the 18th but have not yet attacked. In any case, the people have already lost heart, and the situation cannot be saved. Sooner or later I must die, and I wonder whether my wife is willing to follow me? In a world like this, life is of no use anyway; one might as well come to this conclusion early on. Mother, in your distress you must rely on Fourth Uncle, my cousins, and others in the family for care. Young Zhao\* should do whatever he thinks best for himself. I write no further; my heart\* is rented to pieces.”

*Sent by Kefa, 4th month, 21st day<sup>109</sup>*

The raw emotions that Shi expresses through his last letters offers us a window into the mindset of an exemplary confucian official in times of extreme crisis. Shi likely contemplated his suicide while in Nanjing, because prior to committing back to Yangzhou, Shi had to fight another supposedly Ming-loyalist force. Shi was a man of principles with a firm sense of confucian right and wrong. After witnessing betrayal, disloyalty, and disbelief in the dynasty, Shi probably plunged into a deep depression. His ambitions crumbled before him, as he witnessed every last glimmer of hope for restoration fade away. On top of seeing the defense of Yangzhou as a heroic act in the face of a formidable enemy, it was also accurate to assume that it was a suicide attempt by a depression-riddled man. However, it is key to notice that his letters do not mention ethnicity, or loyalty to the people. The state and loyalty without the element of ethnicity was Shi's focus. Loyalty to the Han identity is almost nonexistent in the surviving letters of Shi Kefa. As a literati, his responsibility to the state inevitably evokes a sense of loyalty, yet this loyalty does not translate to the love of his people.

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<sup>107</sup> Ibid, pg. 31

<sup>108</sup> Ibid, pg. 31

<sup>109</sup> Ibid, pg. 31

Four days later, the Qing army entered the city. Shi was thus taken as a prisoner of war, and summarily executed<sup>110</sup>. Shi might've been able to avoid death, since he was offered surrender again in exchange for a position in the government, an offer he vehemently refused.

“I've asked for your surrender politely with letters, but sire did not comply. Now that you've shown your fidelity and righteousness, you could proceed to hold a new important position-help me take Jiangnan.” - Dodo<sup>111</sup>

“I shall fall when the city falls. I have made up my mind. Even if I am torn to pieces, my feelings are still as sweet as maltose. But, do not harm the tens of thousands in Yangzhou.”  
- Shi<sup>112</sup>

The Qing army truly wished to resolve the Southern Problem swiftly and peacefully. Despite mutual hostility, Prince Dodo and Dorgon showed respect for Shi, offering him multiple opportunities to surrender. Infuriated about Yangzhou's futile defense, and Shi's obstinate stubbornness, Prince Dodo ordered the massacre of Yangzhou. The account from Wang Xiuchu<sup>113</sup>, known as the Ten Days Journal of Yangzhou, is the most detailed resource on this historical episode. The knowledge of the Yangzhou massacre was suppressed during the Qing dynasty, and Wang's writings only became widely available around the 1990s. In Wang's account, the city was reduced to ruins, with bodies strewn across every corner<sup>114</sup>. Women were herded en masse in ropes like cattles, play things, or properties to exchange for ransom. The battle of Yangzhou was an unexpected battle that the Manchu did not want to participate in. As the invader, the Manchu did not carry racial hate or disdain towards the Chinese. In fact, the Manchu army at the time<sup>115</sup> had a great amount of diversity. However, massacres like these sowed the hate for Manchu in general because the leaders were of true Manchu origins. What is also surprising is that Wang's account does not mention racial hatred towards the Manchu.

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<sup>110</sup> Thanks to the collection of Wakeman, the source is from Dodo's Report, cited in Deng Zhicheng, *Gudong Suoji Guanbian*, p. 399. Dodo's report is cited in Deng Zhicheng, *Gudong suoji quanbian*, p. 399.

<sup>111</sup> Dai Mingshi, *Yi-Chou the records of the defense of Yangzhou*, scroll first. Dai Mingshi is quite a controversial historian. Although he was a renowned Hanlin Academician in the court, he was later executed for violating the Qing censorship.

<sup>112</sup> *Ibid*, scroll first

<sup>113</sup> Struve, *Voices From the Ming-Qing Cataclysm*, pg.30-31

<sup>114</sup> *Ibid*, pg. 36. Struve had done incredible translation work on Wang's account in her chapter on Yangzhou Massacre “Several dozen people were herded like cattle or goats. Any who lagged were flogged or killed outright. The women were bound together at their necks with a heavy rope—strung one to another like pearls. Stumbling with each step, they were covered with mud. Babies lay everywhere on the ground. The organs of those trampled like turf under horses' hooves or people's feet were smeared in the dirt, and the crying of those still alive filled the whole outdoors. Every gutter or pond that we passed was stacked with corpses, pillowing each other's arms and legs. Their blood had flowed into the water, and the combination of green and red was producing a spectrum of colors. The canals, too, had been filled to the level with dead bodies.”

<sup>115</sup> At this point the Banner Army already included Mongol, Chinese, and Manchu contingents.

Regardless, the Yangzhou massacre was one of the most prominent talking points of Han nationalists in the early Nineteenth Hundreds. Even today, the event seems to be shadowing the horrible Nanjing Massacre<sup>116</sup>. What is interesting is also how surgical the violence was in Yangzhou. Prince Dodo, who led the army, ordered an indifferent plunder of the city, and then cut down the chaos swiftly after ten days. Despite all of that, a great majority of participants of the massacre were of the green banner soldiers, which consisted of Northern Chinese that surrendered to the Qing. Considering the context, massacres and atrocities were the norm during the tumultuous transition. What Qing brought forth to the Chinese populace was at least the mercy of a precise design of violence, or the quelling of other bandits. These expectations pushed the conquest momentum to the max, helping the Qing make quick advances, so much so that they were able to overrun the Southern Ming capital within the same year.

### **The Hongguang Court's collapse**

Amid his time in Nanjing, Ma Shiyong (another highly ranked Southern Ming<sup>117</sup> official)'s series of political maneuvers, purges, and other actions had alienated many of the southern literati<sup>118</sup>. An illustrative instance unfolded when Zuo Liangyu, a warlord in the modern day Wuhan region, submitted to the Hongguang court. However, Zuo later revolted, advancing toward Nanjing under the banner of “Qingjunce” (Clear the Lord's corrupt officials)<sup>119</sup>. Zuo's army would later prompt Shi Kefa's hasty recall, severely hampering the defense efforts.<sup>120</sup> In 1645, news of the Manchu's brutal actions in Yangzhou reached Nanjing, triggering widespread chaos<sup>121</sup>. Capitalizing on the situation, Ma orchestrated the execution of his political rivals within Nanjing<sup>122</sup>. General Zuo, who had initially been stationed in Wuchang near modern Wuhan, redirected his forces to confront Ma and Ruan. He accused them of treachery and harboring corrupt ministers around Hongguang. Consequently, the former Ming capital experienced a strict lockdown and martial law. Cannons were erected, and ships formed cordons in anticipation of a potential siege. With the populace fearful of repercussions, open discussions ceased and urban life in Nanjing ground to a halt. Citizens refrained from illuminating lamps at night to avoid unwanted attention from soldiers.<sup>123</sup>

Yao Wenxi, a member of the literati class, worked as a tutor in Nanjing and was fortunate to have connections that shielded him from the violence outside. However, the tension in the city escalated steadily. One evening, while taking a stroll near the West Floral Gate, Yao observed armed court eunuchs transporting chests toward the South Gate Boulevard. The following night,

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<sup>116</sup> The Nanjing Massacre was carried out by Japanese invasion forces during world war two.

<sup>117</sup> The Ming court was forced to relocate to its Southern Capital, and Hongguang was the Southern Ming's first emperor.

<sup>118</sup> Struve, Cambridge History of China, Chapter on Southern Ming, pg. 649

<sup>119</sup> Ibid, pg. 655-658

<sup>120</sup> History of Ming, 274th scroll, “可法乃趋天长，檄诸将救盱眙。俄报盱眙已降大清，泗州援将侯方岩全军没。可法一日夜奔还扬州。 The History of Ming is the official record written and compiled by the Qing court.

<sup>121</sup> Struve, Voices From the Ming-Qing Cataclysm, pg. 58

<sup>122</sup> Ibid, pg. 58

<sup>123</sup> Ibid, p. 58

soldiers warned Yao and his family to keep their windows shut and remain indoors. The night was filled with the clamor of soldiers and carriages moving through the streets. On that very night, Hongguang and his entourage fled the Imperial city leaving the palace vulnerable to looters. Yao's uncle, Zilai, ventured into the palace the next morning, discovering ransacked halls and a crowd of curious onlookers. In the ensuing days, common citizens continued looting, while court ladies who had been left behind absconded with gold and silver. The mob eventually descended upon the eunuch compound, where they discovered the palace's wine stockpile, leading to drunken parades and an increase in robberies. People then commenced barricading their homes with whatever materials were available.<sup>124</sup> Patriotism disappeared. The desecration of the former palace was the biggest sign that the Ming dynasty no longer commanded the people. Despite this, the Nanjing mob also paraded and humiliated Ma Shiyong's relatives because of the rumor that Ma corrupted the emperor.

Civil order in Nanjing crumbled for three days. General Zhao Xincheng, in command of the Nanjing garrison, fortified himself within his compound. Upon the arrival of Prince Dodo and his bannermen, the Nanjing garrison promptly surrendered. Zhao Xincheng had been negotiating a peaceful handover of Nanjing to the Manchus. Consequently, the Qing swiftly assumed control of the imperial city, with banners stationed at guard posts.<sup>125</sup> The previous elusive civil officials reemerged, vying for positions in the new empire. Alongside them the Manchu bannermen brought a somber grim sight: thousands of women, harshly whipped as they marched through the city. As Yao recounted, the women seemed like pigs being herded to their pens. This heart-wrenching spectacle moved many bystanders to tears.<sup>126</sup> Initially, only soldiers were mandated to adopt the Manchu policy of shaving their heads, but soon all men in Nanjing faced death if they refused to conform and sport the distinctive pigtail.<sup>127</sup> The act of shaving, particularly for Chinese men who cherished their hair and held it in high regard, was emotionally traumatic.

We young men cherished our hair,\* and when we saw people with shaved heads, they didn't seem human. At first some of us hid out, unwilling to shave; but later we didn't see anyone on the streets unshaven. We had to shave. Old Master Sheng, who'd been in charge of the imperial hunting park, lived not far from my family. But we saw only his butler, carrying a net cap<sup>4</sup> and sobbing as he walked back toward Master Sheng's home. We asked him why, and he said, "The old master of my household was unwilling to shave his head and concealed himself in another old gentleman's home. But today, having heard that everyone—big and small—in the whole capital city

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<sup>124</sup> Ibid, p. 58-61

<sup>125</sup> Ibid, p. 62-63

<sup>126</sup> Ibid, pg. 65

<sup>127</sup> Ibid, pg. 63-64

had shaven, he had no recourse but to shave as well. I saw him there crying, heartbroken, with the other old gentleman. And later when I saw him shaven, indeed, he looked very ugly. I can't help but shed tears, too." When he finished speaking, he walked on, carrying the mesh cap and sobbing.<sup>128</sup>

The shave order's intention was to issue uniformity across the country.<sup>129</sup> For Dorgon, it was a way that can bring the rulers and subjects together. What is ironic is that Dorgon actually considered rescinding the rule until many Han officials proposed it again to gain Dorgon's favor.<sup>130</sup> The mandate backfired as it united the social classes of Chinese to a rebellious cause against the Manchu. Unshaved villages began fighting shaved villages. Local demagogues began arousing peasant mobs to form rebel groups against the Qing.<sup>131</sup>

"The peasants could easily accept new rulers far away in a distant capital. But to have these barbarians, these "Tartars," order them to change their Han customs was an affront that many swore they would not accept.<sup>132</sup>"

The conflict suddenly changed. Resistant movements became ethnically and identity based. Previously, only the politically conscious literati seemed to be capable of any patriotism<sup>133</sup>. Lower class rebellions began to pop up across Southern China, causing the new Qing magistrates to lose control of the countryside.<sup>134</sup> While the Qing might not have seen the conflict as an ethnic struggle, the Southern Chinese did. The shave order evoked a new found Ming patriotism within the Chinese peasants, something that could've been extremely helpful for the remnants of Southern Ming.

### **Huang Dazhou's last campaign**

When the Hongguang Court collapsed in April 1645, Prince of Tang fled to Fujian and ascended to the throne as Longwu of Southern Ming on August 18, 1645. Due to the geographical isolation of the Fujian province, Longwu and Huang Dazhou were both eager to "march out of the passes"<sup>135</sup>. Huang and Longwu were devout Confucian scholars that emphasized virtue and morality. Their outspokenness earned the distrust of Chongzhen, who threw Longwu into jail for Longwu's growing role in the political scene. The moment Huang touched down at Fuzhou, he began to assemble an army to march North and reclaim Zhejiang.

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<sup>128</sup> Struve, *Voices From the Ming-Qing Cataclysm*, pg. 64-65

<sup>129</sup> Wakeman, *The Great Enterprise*, pg. 647

<sup>130</sup> *Ibid.*, Pg. 647

<sup>131</sup> Wakeman, *The Great Enterprise*, pg. 649-650

<sup>132</sup> Wakeman, *The Great Enterprise*, pg. 650

<sup>133</sup> Wakeman, *The Great Enterprise*, pg. 649

<sup>134</sup> Wakeman, *The Great Enterprise*, pg. 651

<sup>135</sup> Struve, *Voices From the Ming-Qing Cataclysm*, pg.123

“It is regrettable that people there have followed one another in fearful avoidance of harm and offered themselves up obeisance to the enemy. Han Huaiyin once said, “People’s hearts become set over time and are hard to move.” This servant, however, fears that if moved after a long time, they will be hard to settle again”<sup>136</sup>

Huang Dazhou set out with the optimistic belief that people from all over will rally to his imperial cause. His troops numbered around 3800 at the start of his campaign. His corps was perhaps the only able-bodied fighting force in Southern Ming that was under direct government control. The most powerful military force was under the Zheng family who made their fortunes as pirates. The current head was a calculating opportunist on the verge of surrendering to the Qing, while his son, later known as Koxinga, was the famous Ming loyalist who would later take Taiwan. Huang was eager to move out of Fuzhou out of fear that they would lose the right timing. Indeed, all is not lost for the Southern Ming. After capturing Nanjing, the Qing army faced a paradox: they cannot assume effective control of Southern China even if their army bloated to a quarter of a million.<sup>137</sup> The reason is that the bloated military numbers were largely due to supposed Ming soldiers surrendering en masse. The Ming soldiers at the time were mostly stragglers and opportunists that fled in the face of an actual battle. Amongst them, were also a great number of surrendered rebels and generals that brutalized the local population.<sup>138</sup> So much so that the local population looked to the Manchu Army as a force of salvation that can rescue them from the local armed brigands. This was a hard pill to swallow for most Confucian scholars at the time. High Ming officials seemed to share a completely different world view from the regular Chinese peasants, Huang was one of them. Though he sometimes acknowledged the desperate situation that surrounds the Ming, he nevertheless believed that patriotism was inherent in every man.

“Those recruited by this servant constitute one-third; the other two-thirds are men brought by his sons, brothers, and maternal relatives. Surely they have not come merely in response to the leadership and rallying cries [of their family members and superiors]. Beyond that is their determination not to discard honor toward their Ruler-Father, not to let the demarcation between [barbarians and Chinese] vanish. Each man, holding his bedroll, has risen up for the Throne.”

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<sup>136</sup> Ibid, all accounts of Huang Dazhou in this chapter are taken from the same Struve work.

<sup>137</sup> Wakeman, *The Great Enterprise*, pg. 593

<sup>138</sup> Wakeman, *The Great Enterprise*, pg. 593



Yet reality was always worse than what he expected. His letters to abled men and leaders asking for their help across Southern China elicited no responses. However, the magistrate of Jinyang supplied him with much needed funds. Moreover, Huang claimed that local leaders supplied him voluntarily with funds, and able-bodied men, which was said to be a great financial burden. Nevertheless, Huang proceeded to march North in efforts to reclaim the support of the northern territories. The army became sick due to the unusual November heat in Fujian, which crippled half of his army.

“When local heroes from Huizhou come to see this servant and find that he can give them positions only as captains’ aides, they look at each other in dismay, throw the certificates on the ground, and leave, saying, “We’ll go see an enlightened ruler and get titles as high nobles.”

He thought his campaign up North would reclaim the hearts of Ming subjects and rally them under his cause. As it turns out, the lower class of Chinese are much more interested in personal well being other than the state. In fact, the learning gap (and wealth gap) between the scholar gentry and local peasants was big enough to make sure that patriotism was an upper class privilege. The scholar gentry class held a responsibility to impose public order, which rests upon the stability of the state. Loyalty to the state was of a paramount concern for virtue. In the face of the Ming collapse the virtue was expressed in suicide. In 1644, when Jiangnan heard the death of the Chongzhen Emperor, hundreds of local nobles committed suicide in various forms. Entire families were driven into suicides, in instance a scholar-official drove his entire family off a cliff, and then jumped into the bodies himself.<sup>139</sup> Patriotism was a moral baggage held on dearly by the scholar-gentry class. The only ones who could hold such strong reverence for the state exists within a tiny fraction of Chinese society<sup>140</sup>. For the average Chinese peasants, the state, the Manchu, or what, did not matter when all sides saw them as merely materials to be used. That is, until the shave order came into effect.

Huang Dazhou would later be captured and executed by the Qing army. His last act was refusing solid food from anyone.<sup>141</sup> The court would collapse in late 1646, and Longwu was executed immediately upon capture. The next legitimate Southern Ming monarch then embarked on a treacherous escape into Burma, where he and his entire family was turned over to Wu Sangui, who strangled them with bow strings.

### **The Qing Court: Dorgon, Shunzhi, and other reflections**

In the letter that was sent to Shi Kefa, Dorgon did not write the letter himself. It was done in the hands of the famous literati - Li Wen, a southerner who surrendered to Qing service much

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<sup>139</sup> Wakeman, *The Great Enterprise*, pg. 598-600

<sup>140</sup> Wakeman, *The Great Enterprise*, pg.

<sup>141</sup> *Ibid*, pg. 123-140

earlier in the conflict. Even the ideas within the letter were not by Dorgon. The formulations contained in the letter reflect a broader strategy Dorgon adopted from his Han officials: to emphasize righteousness. Fan Wencheng was one of the core officials. His surrender to Qing was a product of Nurhaci's conquest of the Han Chinese Liaodong, and the city of Fushun.<sup>142</sup> Ironically, the same Han officials that contributed to the doom of Ming, also preserved the traditions and cultures of the Ming institutions. Feng Quan, another member of the "turncoat officials", strongly advocated the adoption of a series of Confucian bureaucratic measures to erase the separation between Manchu and Han officials. His loyalty to the Qing regime can be summarized by his own quote: "I was born of Ming bones and Qing flesh".<sup>143</sup> Dorgon worked with this court to advance one of key themes of his conquest: to promote ethnic harmony. He declared that the Empire was a single whole, and that manchu-Han distinctions are naught<sup>144</sup>. Yet, Dorgon was keenly aware of the drastic differences between the two. For a long time he had been eager to adopt the shave head rule, which forced Han Chinese to adopt the same hairstyle as the Manchu. However, Dorgon still held reservations, and was willing to waive the requirements. It was thanks to the voluntary efforts of Feng Quan and his allies(which entails appearing before Dorgon in Manchu hairstyle and urging him to adopt the policy nationwide)<sup>145</sup>, that Dorgon issued the infamous edict which forced every Han to adopt the hair style. The decision proved to be an imprudent strategy, because it pushed a great deal of Southerners into an endless warfare with the Qing.<sup>146</sup> Instead of uniting the Hans and Manchus, the policy united both the rich and poor in the South to join up in defense. Perhaps this policy was the defining piece that separates the Qing from Liao, Jin, and even the Yuan. The ferocity of warfare in the transition period, at one time, turned into a ethnic, cultural struggle. The Manchu integration strategies backfired as it incited cultural rebellions. While the vast majority of statesmen, peasants, and soldiers alike lacked a veneration for the state, the endangerment of a cultural heritage was something that truly ignited a more robust rebellious front. For the Han officials and generals that surrendered to the Qing, most of them still existed on a pendulum of changing loyalties. When Koxinga, the most powerful Ming-loyalist warlord in the South, was besieging the now Qing held Nanjing, he intercepted a letter from a Beijing Qing official to Nanjing.

“News from the Southern Capital has been cut off for a long time. Rumor has it that the iron troops<sup>147</sup> are invincible, and it has been proposed that the capital be moved to a remote place to seek refuge from war. You can sense the overall situation from that. You may encourage our children to make overtures of allegiance to the

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<sup>142</sup> Zhou, Ruchang (2009). *Between Noble and Humble: Cao Xueqin and the Dream of the Red Chamber*. Peter Lang. p. 72

<sup>143</sup> Wakeman, *The Great Enterprise*, pg. 873

<sup>144</sup> *Ibid*, pg. 873

<sup>145</sup> Wakeman, *The Great Enterprise*, pg. 868

<sup>146</sup> Wakeman, *The Great Enterprise*, p. 650

<sup>147</sup> The Iron troops refer to Koxinga's household heavy infantryman.

Imperial Surname(Zheng/Zhu Chenggong), paving the way for my defection to him in the future.”<sup>148</sup>

State loyalty existed on two separate extremes. On one hand there is the corps of scholarly officials willing to kill themselves and their families to repent for their sins of ill rescue of the dynasty. And then there is the majority of the court of Southern Ming that surrendered en masse to Dodo when he opened the doors of Nanjing. Nevertheless, the majority are the defectors. Nevertheless, the Qing admired several of the Ming that showed utmost loyalty. The letters back and forth between Dorgon and Shi Kefa were discovered by the Shunzhi<sup>149</sup> Emperor after the death of Dorgon. Particularly, he was impressed by Shi Kefa’s undaunted determination and brilliance expressed in Shi’s letter.

“When zhen(朕)<sup>150</sup>was still young, I heard of my regent, Prince of Rui’s letters to the Ming official Shi Kefa, but I never saw its actual passages. Yesterday I was editing the past achievements of the family, and so I had the opportunity to read the letter for Shi Kefa... Shi Kefa was a wise official, as he maintained his righteousness. But if we do not record his words, would others deny his loyalty? If there are no recordings of his words, then the later generations will not know his actual beliefs, and will have to question him. This is not acceptable. So I ordered the confucian officials to find related books in the markets and collectors. I was not able to find his work anywhere. But finally I discovered it in the file base of the cabinet. After reading through it multiple times, I feel regretful for his loyalty, but also a profound recognition of Prince of Fu’s lack of intelligence(Hongguang Emperor).”<sup>151</sup>

The Qing had a quiet but profound admiration for individuals holding out to the last in the name of the Ming dynasty, despite the fact that their conquest was very much eased by their compliance.<sup>152</sup>The scholars who surrendered have their own explanations. When Qian Qianyi, a surrendered official, visits the camp of Dodo after the fall of Nanjing, collapsed in front of the captured Hongguang emperor. His decision was made based on the fact that his compromise

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<sup>148</sup> Lawrence C.H Yim, the poet historian Qian Qianyi, p.109

<sup>149</sup> Shizu of Qing, or “Worldly Ancestor of Qing”

<sup>150</sup> Zhen refers to the “I”, as in how a Chinese emperor would address himself.

<sup>151</sup> Tung-Hua Lu, fourth scroll, Tung-Hua Lu was edited and compiled by the court historian Jiang Liangqi in the 18th century

<sup>152</sup> Wakeman, The Great Enterprise, pg. 588

could bring about peace and safety for his fellow literati. It is fair to say that Qian made the sacrifice at the cost of being portrayed as a turncoat for the rest of his life.<sup>153</sup>

The collapse of Ming brought about changes that fundamentally shaped Chinese civilization. It was a process of redefining the concept of China, and the world around it. The cosmopolitanism, and the ethnic subjugation of Han Chinese underneath the Manchu elites proved to be a potent force in the formation of a new Han identity. The Ming-Qing conflict proved itself to be an ethnic struggle with the initiation of the shave order. While many literati across the south possessed a profound patriotism, it was the shave order that pushed the lower peasants to adhere to the Ming loyalist cause. Possibly, both the surrendered Chinese officials and lowly peasants believed in the duality between nation and culture. The change of rulers, regardless of ethnic identities, does not influence one's cultural life. However, the great Ming-Qing conflict shattered that expectation. While the Manchu overlords hoped for a swift political conquest, they found themselves in deep cultural strife. For other contemporaries in the seventeenth century, none could have expected that the great enterprise of a Han Chinese rejuvenation would end up in the jaws of another group of foreign "barbarians". The glories and legacies of Yongle<sup>154</sup>, Hongwu, Renxuan all went to naught in the span of a few decades. Yet, even in the last moments of the Ming, there were many faithfuls that defended its institution. In the great Chinese novel, *Dream in the Red Chamber*, the life of a great noble house flashes in front of our eyes, only for it to decline so suddenly, and then disappear into nothing when the narrator wakes up from a dream. For the Ming romanticists, the dynasty was like an elusive dream that punished them with the pain of remembering its few bits of goodness. The feeling was a sense of loss not only for the nation, but also one's cultural identity.

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<sup>153</sup> Ibid pg. 589

<sup>154</sup> Era names for the High Ming. The Yongle, Renxuan eras were the golden ages of the Ming dynasty.

### Works Cited

- Wakeman, Frederic. *The Great Enterprise*. Berkeley, University of California Press, 1985.
- Lynn A. Struve. *Voices From the Ming-Qing Cataclysm*. New Haven, Yale University Press, 21st January 1998.
- Liuqi, Ji, *Northern Records of the Ming Dynasty*(*Mingji Beilue*, 明季北略). Beijing, Zhonghua Book Company, published in 1984, written in around the mid seventeenth century, exact written date is unknown.
- Tingyu, Zhang. *The History of Ming*. Beijing, Wuying Palace Royal Press, 1739.
- Ji, Hao. *The Reception of Du Fu (712-770) and His Poetry in Imperial China*. Leiden, Brill, 2017.
- Yim, Lawrence C.H. *Poet-Historian Qian Qianyi*. London and New York, Routledge, 2011.
- Zhou, Ruchang, et al. *Between Noble and Humble: Cao Xueqin and the Dream of the Red Chamber*. New York, Peter Lang, 2010.
- Jiang, Liangqi. *Dong-Hua-Lu*(*东华录*). Shanghai, Gunagbai-Songzhai, tenth year of Guangxu(1884).
- Fairbank, John King et al. *The Cambridge History of China-Southern Ming Chapter*. Cambridge, Cambridge University Press, 2002.
- Wakeman, Frederic E. "China and the seventeenth-Century crisis." *Late Imperial China*, vol. 7, no. 1, 1986, pp. 1–26, <https://doi.org/10.1353/late.1986.0006>.
- Wen, Bing. *Jiayi Shian*(*甲乙事案*). Donald Sturgeon's Chinese Text Project, 2006-2023.
- Wen, Ruilin. *Nanjiang Yishi*(*Southern Frontier's lost history*, 南疆逸史). Donald Sturgeon's Chinese Text Project, 2006-2023. <https://ctext.org/wiki.pl?if=en&res=3184177>
- The Historical Records of the Qing Ancestors*(*Qing Shizu Shilu*, 清世祖实录). Donald Sturgeon's Chinese Text Project, 2006-2023. <https://ctext.org/wiki.pl?if=gb&chapter=897415&remap=gb>
- Hsiu Shushen. *The Records of the Founding Father Sun Zhongshan as the Temporary President*(*國父當選臨時大總統實錄*). Taipei, National History editorial Institution. 1967
- Dai Mingshi. Records of the defense of Yangzhou in yi-you. Donald Sturgeon's Chinese Text Project, 2006-2023. <https://ctext.org/wiki.pl?if=en&res=6957052>
- “Spring Gaze,” by Du Fu: Asia for Educators: Columbia University.” “*Spring Gaze,*” by Du Fu | *Asia for Educators* | *Columbia University*,

afe.easia.columbia.edu/special/china\_600ce\_dufu.htm. Accessed 15 Oct. 2023.

Translated by Pauline Yu of University of California Irvine.

Klinck, Anne L. *The Old English Elegies: A Critical Edition and Genre Study*. Montreal, McGill-Queen's University Press, 2014.

## **Predicting the Emotional Exhaustion of Medical Students Using Behavioral Factors and Machine Learning Techniques By Pranav Joshi**

### **Abstract**

Medical students undergo high-stress levels, causing unnoticed mental illnesses and burnout. In order to improve the education of medical students and better support health professionals for their careers, this paper works to ascertain poor mental health. This project analyzed visible factors such as empathy, emotional intelligence, and cynicism to predict mental health levels and inform those surrounding medical students of an individual's potential emotional state. After refurbishing medical student survey data, regression, classification, and neural network models were tested in order to elicit the highest accuracy. Neural networks output the most accurate predictions of emotional exhaustion. The results showed that gender played a minor role in burnout but was not nearly as pronounced as previously analyzed. Cynicism was a prominent indicator of emotional exhaustion, although empathy scores were not indicative. Although machine learning techniques showed promising results, these techniques only provide context and reason to address mental health concerns. However, with the combination of voice analysis, computer vision, and current methods, machine learning could inform treatment plans and provide more information about mental health for medical students.

### **Introduction**

For years, observations have shown that medical students endure heightened stress and are prone to many mental illnesses. From the stress of challenging exams, crammed schedules, uncertain career paths, and the necessity of performing at the highest caliber, medical education takes a significant toll on those involved. However, due to the high stakes, little time, and lack of prolonged interaction with loved ones, it is extremely easy for mental illnesses and burnout to go unnoticed in medical students. Past papers have frequently utilized academic factors and aspects of life that are unnoticeable to determine students' mental health. These analyses rely on truthful self-reported survey answers from medical students. Factors that can be discerned and estimated through human interaction and behavior observation, like empathy and emotional intelligence, are an untapped methodology for discerning mental states. This paper aims to utilize machine learning techniques to analyze the factors behind emotional exhaustion in medical students and

provide accurate predictions of students' mental health states. It aims to provide empathy, emotional intelligence, cynicism, and more as outward expressions that can indicate mental illness in students. Surrounding parties could utilize this new approach to ascertain a student's emotional state and provide the intervention or help needed. Students could also utilize this approach to gain perspective on their mental health and make the necessary changes to prevent mental illnesses from developing. Based on a dataset that collected characteristics, empathy scores, and burnout scales for medical students, this paper tests several regression and classification approaches and tunes them to predict levels of mental health accurately. It then compares the underlying relationships and predictions with previous assumptions of mental health in medical students and results from linear regression with the same dataset in Carrard et al.

## **Background**

This section covers background information on the Maslach Burnout Inventory, relevant mental health research, a review of machine learning techniques for mental health research, and the metrics utilized to evaluate model accuracy in this paper.

### **1. Maslach Burnout Inventory**

The Maslach Burnout Inventory is a psychological assessment that applies to occupational burnout. The general survey format administered to collect the dataset used in this paper measured emotional exhaustion, cynicism, and academic efficacy. Other relevant factors, such as cognitive empathy, affective empathy, and emotion recognition, were measured to understand medical students' emotional intelligence. The MBI has been influential in understanding burnout and its impact on individuals and organizations, and it has contributed to the development of strategies to address and prevent burnout in various settings.

### **2. Mental Health of Medical Students**

Carrard et al. associated higher cognitive and behavioral empathy levels with a lower concentration of mental health issues. Utilizing logistic regression, Jafari et al. have shown that 1st-year and female medical students are at the highest risk of developing mental illnesses. Countless previous studies, such as Imran et al., utilized academic factors such as frequency of exams, studying time, lack of guidance, and fear of failure as indicators of deteriorating mental health. However, very few studies other than Carrard et al. utilize behavioral and empathy factors to predict mental health levels.

### **3. ML Techniques for Mental Health**

Shatte et al.'s scoping review of machine learning techniques in mental health applications revealed that most studies focus on detecting and diagnosing illnesses. While our paper is similar in that aspect, it varies from the most common machine learning technique identified in the review, supervised classification. Because of the sensitivity of mental health and such information, many previous papers utilized survey data to analyze mental illnesses. Frequently utilized types of medical data in papers aiming to detect mental illnesses include patient information, social media data, and more.

### **4. Model Metrics**

The primary metrics utilized in this paper were mean absolute error for regression and accuracy score for classification. *Mean absolute error* is a metric that assesses the absolute difference between predicted values and actual observations. These absolute differences' average (mean) is the MAE. The formula for this dataset where the y variable is equivalent to the emotion exhaustion score and n is the number of students is:

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i|$$

MAE measures how far, on average, the model's predictions are from the actual values. A lower MAE indicates that the model's predictions are closer to the actual values, signifying better accuracy. MAE directly represents the average absolute error in the same units as the target variable and is less sensitive to outliers than other error metrics like Mean Squared Error.

*Accuracy score* is a specific evaluation metric used in classification tasks. Accuracy Score measures the proportion of correctly classified instances out of the total instances in the dataset. In the following equation used to calculate accuracy scores, TP stands for True Positives (correctly predicted positive instances), TN stands for True Negatives (correctly predicted negative instances), FP stands for False Positives (incorrectly predicted positive instances), and FN stands for False Negatives (incorrectly predicted negative instances):

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

A higher accuracy score indicates that the model's predictions are more accurate and aligned with the actual class labels in the dataset. Accuracy Score is easy to understand, provides a single scalar value for model performance, and is particularly useful when classes in the dataset are balanced. However, high accuracy can be misleading in situations where one class dominates the dataset, and other evaluation metrics (such as precision, recall, or F1-score) may be more appropriate.

## **Dataset**

This project used the data from the paper by Carrard et al. The dataset contains the survey responses of 885 medical students, each with 20 features. Behavioral metrics include the MBI emotional exhaustion, MBI cynicism, and QCAE Affective empathy scales. Other background features include years of medical school, sex, and satisfaction with health. Carrard et al. collected the data by sending online surveys to University of Lausanne medical students, with general questions and several emotional intelligence tests. All numerical features were scaled from 0 to 1 to normalize the data. We removed the age feature from the data due to its similarity to the curriculum year feature and its effect on the accuracy of classification and regression models. We removed the mother tongue and recent psychotherapy features because they did not affect the results. All other features increased the effectiveness of the models. The ratio of training to testing data was 80 to 20.



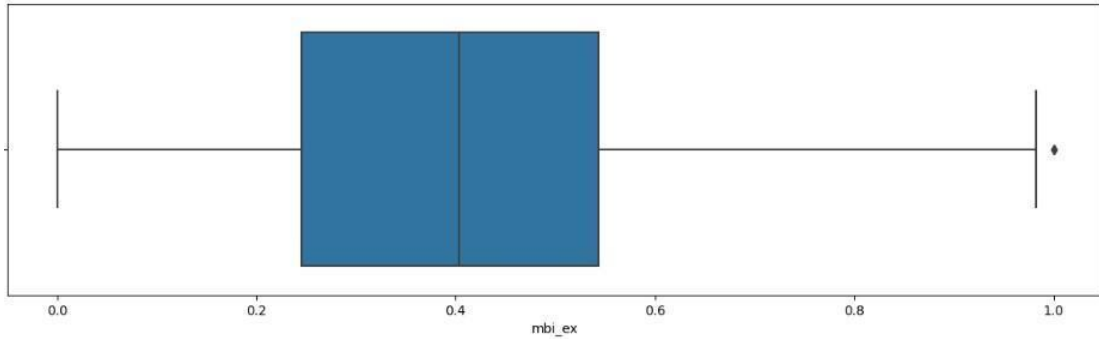


Figure 1: Distribution of Emotional Exhaustion among Medical Students

## Methodology

To explore potential solutions for the problem, the paper utilized the dataset with various models to provide the most efficient output. After fitting a basic model, the hyperparameters would be isolated for change one by one to find the best value for each parameter. The original results and the tuned model would be evaluated with the mean absolute error metric for regression models, accuracy score for classification models, and training and validation loss when applicable. To determine the underlying relations of features to the level of mental health, the paper graphed specific features against the model output.

### 1. Basic Regression Models

While undergoing initial trials for regression, Lasso regression, Random Forest Regression, and Decision Trees Regression were utilized. We altered hyperparameters to improve the error after initializing each model and analyzing the output with mean absolute error. For each hyperparameter, we graphed accuracy scores against increments to distinguish the optimal value of the parameter and the effect that the parameter had on the results. Depth and Nodes were tested the most across the models as they caused significant variances, while other parameters, such as iterations and estimators, were also considered.

### 2. Classification Models

In order to adjust the data for classification, the paper encoded emotional exhaustion output data so that scores above the 75th percentile were represented by 1, and scores below the percentile were recorded as 0. When attempting multiclass classification, the paper encoded scores up to the 50th percentile as 0, from the 50th to 75th percentile as 1, and above the 75th percentile as 2. While undergoing trials for the Ridge Classifier, the methodology and modifications were highly similar to those of the basic regression models. For the CatBoost Classifier from Prokhorenkova et al., we utilized the hyperopt library to determine the initial values for the learning rate and  $l_2$ =leaf-reg. After further trials with hyperparameters to optimize the model, we implemented a learning rate scheduler to adjust the learning rate during training after a certain number of steps. This implementation reduced training time and optimized the model further.

### 3. Neural Networks

We included the psychotherapy feature in the trials for the data utilized with the Neural Network from Keras. The Neural Network ultimately included 5 layers of 2000, 1000, 500, 250, and output nodes. The paper utilized the Adam optimizer to change parameters in real-time, the early stopping technique to prevent overfitting, and a learning rate scheduler to optimize the learning rate. We compared training and validation loss after each trial to monitor possible overfitting. The paper implemented a dropout approach in the model’s initialization as a precautionary measure.

## 5. RESULTS AND DISCUSSION

To build upon the linear regression method utilized on this dataset in Carrard et al., we used several other regression techniques to find a better methodology. The three best performers were the Lasso Regression model, the Random Forest Regression model, and the Decision Trees Regression model. The base Lasso Regression model performed at a mean absolute error of 0.150 and then performed at 0.137 after optimizing the iterations and the shrinkage.

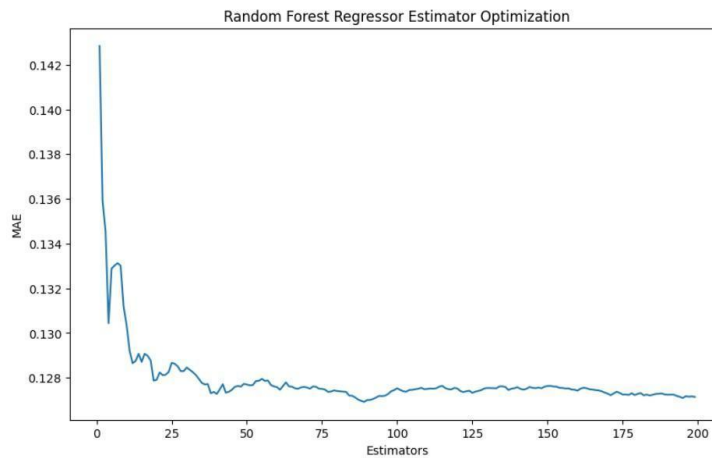


Figure 2: Example of Optimization Loop

The base Random Forest Regression model performed at a mean absolute error of 0.160 and then performed at 0.127 after optimizing the depth, estimators, and maximum number of features. The Decision Trees Regression base model performed at a mean absolute error of 0.149 and then performed at 0.141 after optimizing the depth and criterion. While trying to further optimize the models by adding more importance to certain features or combining them, none of these attempts positively impacted the error. While these models provided some context, more accuracy was necessary to obtain an implementable product.

Table 1: Basic Regression Models’ MAEs

Model	Change	MAE
Lasso Regression	None	0.150

Lasso Regression	Squared Cynicism	0.154
Lasso Regression	Squared CESD	0.156
Lasso Regression	Alpha = 0.3	0.147
Lasso Regression	Max Iterations = 1500	0.138
Random Forest	None	0.170
Random Forest	Depth = 4	0.159
Random Forest	Estimators = 87	0.155
Random Forest	Max Features = 0.8	0.152
Decision Trees	None	0.155
Decision Trees	Depth = 3	0.147
Decision Trees	Criterion = Friedman MSE	0.141

Table 2: Classification Models' Accuracy Scores

Model	Change	Accuracy
Catboost Binary	None	0.887
Catboost Binary	12-leaf-reg = 6	0.912
Catboost Binary	Depth = 5	0.921
Catboost Binary	Remove Age feature	0.943
Catboost Binary	Learning Rate = 0.1	0.938
Catboost Binary	LR Scheduler	0.945
CB Multiclass	All Previous	0.657
Ridge Binary	None	0.916
Ridge Binary	Max Iter. = 2000	0.933
Ridge Binary	Alpha = 0.3	0.938
R. Multiclass	All Previous	0.592

Classification techniques were most accurate for binary classification, identifying scores

above and below the 75th percentile. With no parameter changes, the Catboost classifier performed with an accuracy score of 0.913. After tuning hyperparameters such as depth, learning rate, 12-leaf-reg, and iterations, the accuracy score improved to 0.944. The paper implemented a learning rate scheduler to optimize the learning rate. For the baseline Ridge Classifier, an accuracy of 0.916 was achieved and then improved to 0.938 after optimizing the max depth and the number of estimators. While these developed models were highly accurate, the results of this classification did not have much impact or relevance as there was merely a context of poor mental health and all levels below that. Multiclass classification techniques provided more context for mental health, but accuracy dropped significantly, with accuracy scores of 0.657 for the Catboost Classifier and 0.592 for the Ridge Classifier. Ultimately, binary classification was highly accurate but needed to provide more context to be applied, and multiclass classification had low accuracy.

After determining that regression had more applications and potential for higher accuracy, we explored Neural Network regression. The base neural network had a mean absolute error of 0.127. However, while monitoring the training and validation loss, we noticed the possibility of overfitting. To take preventative measures, we implemented a dropout feature to force the model to find new connections within the data and early stopping. To optimize the learning rate, the paper implemented the learning rate scheduler was once again implemented along with the Adam optimizer from the Keras library. Without the learning rate scheduler and optimizer, the MAE increased. Adding an extra layer to the network, reducing the batch size, and changing the dropout rate optimized the model further. However, with the neural network, new changes in the data had a positive effect. Adding back the psychotherapy feature increased the accuracy. Ultimately, these parameters and data processing changes allowed the neural network technique to reach a low mean absolute error of 0.119.

Table 3: Neural Network MAEs

Change	MAE
None	0.127
LR Scheduler	0.125
Batch Size = 10	0.124
Adam Opt. LR = 0.2	0.124
LR = 0.4	0.122
Layer – 2000 nodes	0.120
Dropout Rate = 0.1	0.120
Add ‘psy’ feature	0.119

The Neural Network provided the best accuracy from the regressors and enough context to be applicable in professional environments. However, the low amount of training data limited the neural network. Because this dataset contained many features and relationships, the model could have uncovered a lot, but there needed to be more available data. The neural network could

have reached a much lower mean absolute error had more survey responses, and future papers can take such measures. With an error of approximately 12%, students falling within the cluster near the median emotional exhaustion score would be judged in the proper context but must be accurately differentiated. Carrard et al. concluded that cynicism was directly proportional to emotional exhaustion while empathy scores were inversely proportional, and this paper came to similar conclusions. However, while Carrard et al. emphasized the effect of gender on emotional exhaustion, the relationship discovered in this paper was not nearly as pronounced. Additionally, the linear relationship between empathy scores would have been more pronounced. Although there may be a slight correlation, empathy scores contributed to the level of mental health in addition to other factors rather than displaying a linear relationship. The relationship between elevated exhaustion in first-year medical students is comparable to the higher concentration of mental health issues in first-year medical students discussed in Jafari et al. Compared to Carrard et al., which determined underlying relationships using linear regression, our paper explored more complex relationships with the use of neural networks and utilized the data to predict emotional exhaustion and mental health.

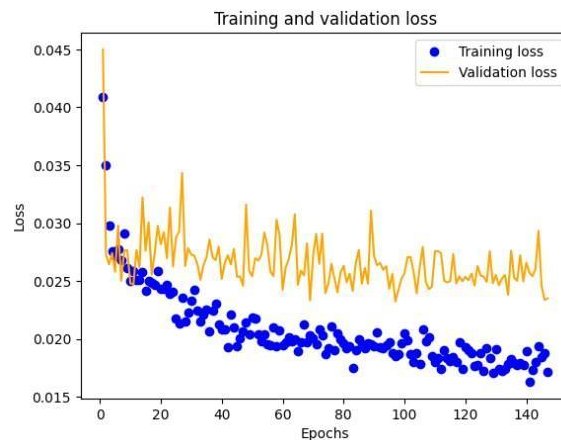


Figure 3: Training vs. Validation loss of Neural Network

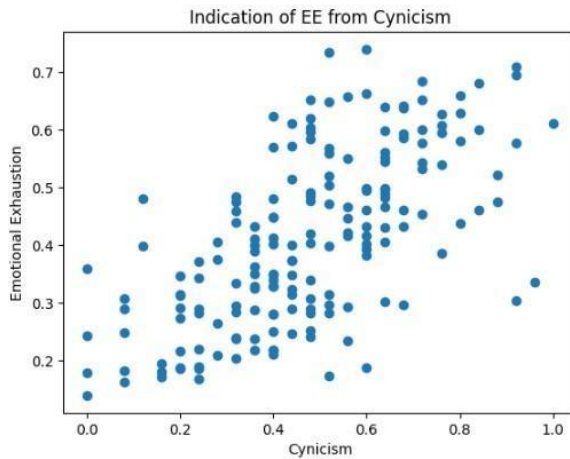


Figure 4: Indication of Emotional Exhaustion from Cynicism

Additionally, the quantitative results of the paper are on the unique side compared to many papers that have utilized supervised classification. However, compared to the few studies that ascertain mental health quantitatively, this paper obtained similar accuracy while using the novel outlook of behavioral factors. Compared to simple regression models and KNNs, the Neural Network in this paper performed equal to or above the results of previous papers. However, this paper was less effective than other neural networks, such as the one tested by Salam et al. and gradient boosting methods. Considering the complexity of the mental health prediction issues, the limited data, and the lack of extensive resources, this is to be expected. State-of-the-art gradient boosting models require extensive tuning, computations, and resources unavailable to this project. Other Neural Networks also succeeded as they were applied to more straightforward relationships and could capture complex relationships due to the large amounts of available data.

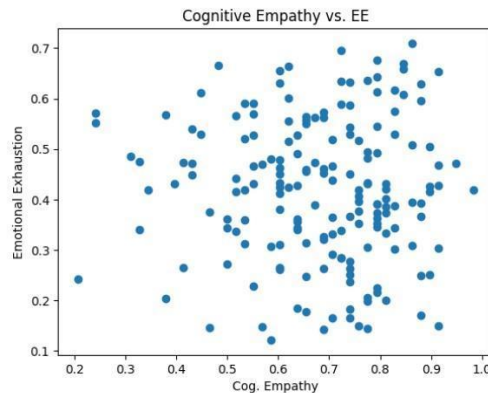


Figure 5: Relationship between Cognitive Empathy and Emotional Exhaustion

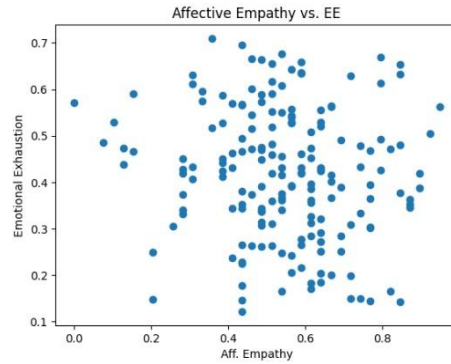


Figure 6: Relationship between Affective Empathy and Emotional Exhaustion

## Conclusions

This study shows a high potential for emotional exhaustion and burnout behavioral indicators in medical students. However, the results can only provide context for individuals on their situations and inform surrounding parties on the potential mental state of students. The results of this study are not ready for clinical applications, but they can be improved. By assessing the mental state of medical students through visible factors, medical programs, professors, and friends will be able to input behavioral indicators and receive an estimate of the level of emotional exhaustion the student is feeling. The output can provide context for intervention, self-management of workload, and initiate peer-to-peer conversation.

With this implementation, medical students will be more likely to complete their programs without mental illnesses and create a better environment for learning medicine. Combining this work with computer vision models that analyze the behavior of medical students through body language and facial expression can exponentially increase the accuracy and plausibility of implementing AI to ensure a positive mental health environment.

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### Works Cited

- Carrard, Valerie, et al. "The Relationship between Medical Students' Empathy, Mental Health, and Burnout: A Cross-Sectional Study." *Medical Teacher*, vol. 44, no. 12, Dec. 2022, pp. 1392–99. *Taylor and Francis+NEJM*, <https://doi.org/10.1080/0142159X.2022.2098708>.
- Cuttilan, Amit Nirmal, et al. "Mental Health Issues amongst Medical Students in Asia: A Systematic Review [2000–2015]." *Annals of Translational Medicine*, vol. 4, no. 4, Feb. 2016, p. 72. *PubMed Central*, <https://doi.org/10.3978/j.issn.2305-5839.2016.02.07>.
- Dorogush, Anna Veronika, et al. *CatBoost: Gradient Boosting with Categorical Features Support*. arXiv:1810.11363, arXiv, 24 Oct. 2018. *arXiv.org*, <http://arxiv.org/abs/1810.11363>.
- Guo, Huifeng, et al. *DeepFM: A Factorization-Machine Based Neural Network for CTR Prediction*. 1, arXiv:1703.04247, arXiv, 13 Mar. 2017. *arXiv.org*, <http://arxiv.org/abs/1703.04247>.
- Jafari, Najmeh, et al. "Mental Health of Medical Students in Different Levels of Training." *International Journal of Preventive Medicine*, vol. 3, no. Suppl1, Mar. 2012, pp. S107–12.



- Kleijweg, Jeroen H. M., et al. “The Clinical Utility of the Maslach Burnout Inventory in a Clinical Population.” *Psychological Assessment*, vol. 25, no. 2, 2013, pp. 435–41. *APA PsycNet*, <https://doi.org/10.1037/a0031334>.
- Salem, Hanaa, et al. “Predictive Modelling for Solar Power-Driven Hybrid Desalination System Using Artificial Neural Network Regression with Adam Optimization.” *Desalination*, vol. 522, Jan. 2022, p. 115411. *ScienceDirect*, <https://doi.org/10.1016/j.desal.2021.115411>.
- Shatte, Adrian B. R., et al. “Machine Learning in Mental Health: A Scoping Review of Methods and Applications.” *Psychological Medicine*, vol. 49, no. 9, July 2019, pp. 1426–48. *Cambridge University Press*, <https://doi.org/10.1017/S0033291719000151>.
- Tate, Ashley E., et al. “Predicting Mental Health Problems in Adolescence Using Machine Learning Techniques.” *PLOS ONE*, vol. 15, no. 4, Apr. 2020, p. e0230389. *PLoS Journals*, <https://doi.org/10.1371/journal.pone.0230389>.

## **Inhalation Anthrax: A Comprehensive Review By Anna Ding**

### **Abstract**

Anthrax, caused by *Bacillus anthracis* (*B. anthracis*), is a zoonotic disease present in all parts of the world. With herbivores as its natural reservoir, all warm blooded animals are susceptible to infection. The disease can only be transmitted through endospore entry into the body, with no documented cases of human to human transmission. Depending on the method of entry, anthrax can manifest in 3 clinically classified forms: cutaneous, inhalational, and gastrointestinal. For the purposes of this literature review, only inhalation anthrax will be discussed. Inhalation anthrax’s high mortality rate and capacity for use as a biological weapon pose a great threat to human and animal populations; this paper seeks to provide a thorough overview of this disease, should future reference be necessary.

### **Background**

*B. anthracis* is an endospore forming bacteria most commonly found in agricultural areas of the world (Hendricks, K et al.). In its endospore state, anthrax is able to remain dormant for

decades and up to centuries at a time, only returning to a reproductive and vegetative state when conditions are favorable. Although anthrax is extremely resistant as an endospore, able to tolerate heating, ultraviolet light, gamma radiation, and a multitude of disinfectants, 10 minutes at 100 degrees Celsius is enough for spore destruction (Kamal, S M et al.).

Anthrax is not transmissible between humans. Only animal to animal and animal to human cases of anthrax have been documented. Inhalation anthrax occurs when anthrax endospores enter the body through inhalation, and gain access to the lungs, where it is transported to regional lymph nodes, enabling bacterial germination, multiplication, and toxin production (Chambers J, Yarrarapu SNS, Mathai JK.). With a survival rate of only 10-15% in untreated patients, it is extremely dangerous. Those working in livestock and animal industries are particularly susceptible to inhalation anthrax, as exposure to infected animal debris can result in infection (Hendricks, K et al.).

## **History**

Anthrax has a long historical record, with an origin possibly traced back to early Mesopotamia and Egypt. The Bible is the first to mention anthrax; Exodus Chapters 7-9 bring up a severe disease consistent with anthrax befalling livestock in 1491 BC. Other outbreaks, such as those in India, are recorded in Hindu literature, with anthrax described in cattle by 500 BC. Early Greek writings also recognized the disease, incorrectly postulating that bovine anthrax was caused by shrew mouse bites. This false belief was perpetrated into the 18th century, hindering investigation into the disease. Ancient Rome likely dealt with anthrax as well, with Virgil describing a livestock plague that spread to humans through ingestion and contact with infected animal material (Sternbach, George.).

Up until the 16th century, little progress had been made in understanding anthrax. A major outbreak in 1613 in southern Europe killed over 60,000 people, leading to the nickname “Black Bane”. Ineffective measures, such as charms and incantations, were often used during outbreaks, in hopes of warding off disease.

Keeping in mind that Germ Theory, the idea that microorganisms can cause disease, was not established and accepted until the late 19th and early 20th century, the misconceptions surrounding anthrax are not surprising (National Research Council, 7). The first scientific literature regarding anthrax was written by Dijon of France in 1769, with his article “Charbon Malin” describing the disease in both human and animal models. In 1823, Professor Éloy Barthélemy was the first to prove the contagiousness of anthrax, by inducing infection through the introduction of blood and lesion material. Following Barthélemy, his student, Delafond, conducted the first microscopic studies of *B. anthracis* in 1860, setting up the stage for Robert Koch (Morens, David M.).

Koch was a well educated medical doctor with a passion for natural science. As a district medical officer in Wöllstein, Germany, he began investigating the disease plaguing livestock and people under his jurisdiction. Prior research into anthrax had shown rod-shaped structures in the

blood of infected animals, and that inoculating healthy animals with diseased blood caused infection. Koch discovered that the blood of the sheep that had died of anthrax, when introduced into a mouse, caused death the following day. The rod-shaped structures present in the sheep blood were found in the blood, lymph nodes, and spleen of the mouse during autopsy. Further, inoculating a second mouse with blood from the first also produced the same result. Koch was the first to link a bacterium to a disease, through his experimentation with anthrax (Steve M. Blevins, Michael S. Bronze).

With additional research with other diseases, Koch developed 4 postulates, now known as Koch's Postulates, to assess whether a microbe is responsible for a disease. They are as follows: "(1) The microorganism must be found in diseased but not healthy individuals; (2) The microorganism must be cultured from the diseased individual; (3) Inoculation of a healthy individual with the cultured microorganism must recapitulated the disease; and finally (4) The microorganism must be re-isolated from the inoculated, diseased individual and matched to the original microorganism."(Segre, Julia A.). A modified version of Koch's Postulates is still used today to determine the link between a microbe and disease.

Now with more available information on anthrax, many attempts were made to develop an anthrax vaccine. Louis Pasteur, famous for disproving spontaneous generation in the 1860s, was the first to succeed. His vaccine was made of an attenuated virus, prepared by adding antiseptics and maintaining 42-43C culture temperatures to prevent endospore formation. It had a 2 dose regimen, with an initial well-attenuated injection and a more virulent one 12 days later. In a public demonstration, sheep, goats, and cows were inoculated, and injected with a live virus after a month. Control animals all showed signs of infection or were dead within 2 days, whereas inoculated animals all remained healthy. The vaccine's success led to widespread livestock vaccination, and a marked decrease in anthrax cases among livestock workers.

Sclavo of Italy's 1895 discovery brought the first treatment of anthrax to man. He produced antiserum in horses, which remained the most effective treatment of the disease for the next 30 to 40 years (Sternbach, George.).

During the 20th century, anthrax's capacity as a bioweapon was recognized. In World War I, Germans intended to spread anthrax to kill off livestock. Various countries took up after Germany, expanding their bioweapons programs during the Interwar Period and World War II. The British bioweapons testing ground of Gruinard Island during World War II led to a decades long persistence of anthrax spores, resulting in a ban on livestock grazing on the island (Johnson, M.P et al.).

A human vaccine for anthrax was developed in 1950, and later improved upon in 1970. The 1972 Biological Weapons Convention led the US and many others to halt their bioweapon programs, and destroy their remaining stocks of anthrax, among other microbes. In 1979, an anthrax breakout occurred in Sverdlovsk, Russia, after spores were accidentally disseminated from a secret bioweapons facility. A worker failed to install an air filter in the facility, leading to a draft of anthrax spores downwind to Sverdlovsk. Of the 95 civilians infected, 68 died from inhalation anthrax.

More recently, anthrax spores were mailed through the US postal service. In 2001, spores were placed in letters and mailed to various news agencies and senators (FBI). As a result, a total of 22 people were infected, 11 of whom developed inhalation anthrax, of which 5 resulted in fatalities (Gursky, Elin et al.).

### **Disease Pathology**

Inhalation anthrax begins with the introduction of anthrax spores into the alveoli of the lungs. On-site phagocytic immune cells endocytose the bacteria, transporting them to nearby lymph nodes. Spores germinate, reverting from their previously vegetative state into active microbes, beginning rapid multiplication and toxin production. As infection progresses, bacteria can enter the bloodstream, incurring bacteremia and sepsis. With bacterial migration, superficial organ ulcerations, soft tissue edema, and necrosis can occur (Chambers J, Yarrarapu SNS, Mathai JK.). Vascular dissemination into the meninges or invasion of the cerebrospinal fluid can lead to anthrax meningitis, causing generally fatal severe edema, necrosis, and hemorrhaging within the intracranial cavity (Nicholas Caffes et al.).

Anthrax's high mortality rate comes as a direct result of its various virulence factors. The bacteria has an antiphagocytic capsule that prevents the host cells from destroying it. Made out of poly-D-glutamic acid, its negative charge is integral in protecting the bacteria (Ezzell, JW, and SL Welkos. ). In addition, *B. anthracis* releases 3 toxin proteins: a protective antigen (PA), lethal factor (LF), and edema factor (EF). The LF and EF can separately combine with the PA to create lethal toxin (LT) and edema toxin (ET), respectively (Brossier, F et al.). Both toxins work to suppress the immune response, though depending on which cells they interact with and the stage of infection, varying inflammatory responses are triggered (Baldari, Cosima T et al.). Specifically, LT impairs lymphocyte activation, B cell proliferation, and it's activation of the cytosolic inflammasome pathway induces macrophage apoptosis, while ET increases intracellular cAMP, inducing the vasodilation that causes edema, while also stimulating the migration of infected macrophages to the lymph nodes and inhibiting T cell activation (Collier, R John).

The cell death and bacterial proliferation caused by these two toxins in conjunction are reflected in the hemorrhagic mediastinitis, pulmonary edema, serosanguinous exudative pleural effusions, and lymph node ulceration seen in inhalation anthrax patients (Bush, L M et al.). Fluid accumulations in particular, namely pleural effusions, pericardial effusions, and ascites, are thought to be caused by vascular leakage and lymphatic destruction associated with EF (Abramova, F A et al.). However, without the PA, both the LF and EF are innocuous, as PA is necessary to mediate toxin entry into the cell, by binding to anthrax toxin receptors (ATRs) on the cell exterior, promoting the endocytosis of toxin complexes, transporting EF and LF into the cytoplasm (Erwin, J L et al.). As such, PA is considered as an important biomarker of anthrax, is the primary target of treatment development, and is often tracked to determine the stage of infection (Savransky, Vladimir et al.).

Current research indicates that anthrax's virulence is attributed to toxemia, rather than a cytokine storm, during sepsis (Day, Judy et al.). Non-human primate models have illustrated that the clinical stages of anthrax align with specific toxin levels, independent of time since exposure in both slow and fast progressing presentations, substantiating the toxin-dependent nature of anthrax's lethality (Boyer, Anne E et al.).

### **Disease Progression**

Due to the incredibly dangerous nature of inhalation anthrax and the rarity of human cases, much of what is known about the disease comes from animal models. Specifically, nonhuman primates, rabbits, and guinea pigs, are among the most commonly used animals. This is due in part to their highly comparable mechanisms of entry, and similar susceptibility to anthrax. Anthrax's disease pathology among all animals is relatively consistent, so these models are effective in predicting pathogenesis in humans (Savransky, Vladimir et al.).

Inhalation anthrax in guinea pigs has been modeled with the aerosolization of *B. anthracis* spores in an aqueous suspension. Using *B. anthracis* Ames strain spores, the suspension was aerosolized and introduced nasally to the guinea pigs, with a set number of viable bacteria. Animals were observed every 6 hours post exposure until the animal was found dead, reached scheduled termination, or was euthanized for its moribund condition. Necropsy examination of euthanized guinea pigs revealed bacteria in the meninges of the brain and mild lymphoid destruction starting 36 hrs after exposure, with increased lesion severity in animals terminated after prolonged infection. Numerical scores from 1 to 4 were given to grade the severity of each lesion, in addition to the degree of bacterial invasion of the tissue. Of the guinea pigs that did not survive to their scheduled euthanization time points, microscopic lesions, hemorrhage of the spleen, lungs, and lymph nodes, and lymphocyte depletion were common findings, typical of disseminated anthrax. Hematoxylin and Eosin (H&E) stained tissue samples further illustrated vast hemorrhaging in lymph node sinuses and extravascular tissues, rod-shaped bacteria in blood vessels, and alveoli infiltrated with fibrin and edema (Savransky, Vladimir et al.).

The study referenced only implanted telemetry transmitters in nine of the subjects studied, measuring heart rate, MAP, pulse pressure, and diastolic and systolic blood pressure, the small sample size resulting in large margins of error in predicting the proportion of each measured attribute that was impacted by the presence of *Bacillus anthracis*. However, the analysis of the telemetric data present give valuable insight into anthrax's disease pathology, with the elevation of heart rate immediately post challenge and for 5 consecutive hours starting 49 hours post challenge, and the decrease of MAP, pulse pressure, diastolic, and systolic blood pressure starting 20 hours post challenge. Combined with the anatomical developments documented via necropsy, animal models give valuable insight into the progression of inhalation anthrax.

A literature review of collated clinical data from documented cases of human anthrax from 1880-2018 reveals a median incubation length of 7 days among the 43 recorded cases between 1960 and 2018, a median 2 days between symptom onset to hospitalization or death (IQR, 0-3), and a median 4 day hospital stay (Katherine Hendricks et al.). A majority of adult

inhalation anthrax patients in this review presented with fever or chills (75.6%), myalgia (70%), dyspnea/cyanosis (66.7), and cough (56.7%), with other notable symptoms of diaphoresis (31.1%), headache (38.9%), chest pain (41.1%), nausea or vomiting (37.8%), and abdominal discomfort (22.2%) (see [table 1](#)). Patients had a mean temperature of 38.1 C, respiratory rate of 28.7 breaths per minute, heart rate of 111.4 beats per minute, and blood pressure of 117.6/73.0 mmHg. These elevated signs align with ones observed in animal models with disease progression (Savransky, Vladimir et al.). Lab tests also showed high rates of leukocytosis (48.5%), high hematocrit (31.8%), thrombocytopenia (44.4%), hyponatremia (58.8%), and hypoalbuminemia (66.7%) for patients who had those data recorded (see [table 2](#)).

**Table 1.** Presenting Symptoms and Signs for 90 Adults Reported to be Hospitalized for Inhalation Anthrax, 1880-2018<sup>a</sup> (Kyriacou, Demetrios N et al.)

Symptoms (n (%))		Signs (Mean ± SD (N)) <sup>b</sup>	
Fever or chills	68 (75.6)	Temperature (oC)	38.1 ± 1.5 (47)
Fatigue/flu-like symptoms/myalgia	63 (70.0)	Respiratory rate (breaths per minute)	28.7 ± 10.5 (33)
Anxiety	18 (20.0)	Heart rate (beats per minute)	111.4 ± 17.6 (41)
Diaphoresis	28 (31.1)	Systolic blood pressure (mm Hg)	117.6 ± 25.7 (29)
Dizziness or syncope	8 (8.9)	Diastolic blood pressure (mm Hg)	73.0 ± 19.2 (27)
Headache	35 (38.9)		
Severe headache	5 (5.6)	<b>Signs (n (%) N)</b>	
Chest pain	37 (41.1)	Fever (>38.0oC, %)	36 (44.4) 81
Dyspnea/cyanosis	60 (66.7)	Hypothermia (<36oC, %)	8 (9.9) 81
Cough	51 (56.7)	Tachypnea (>20, %)	26 (38.8) 67
Cold symptoms/coryza or nasal congestion/pharyngitis	18 (20.0)	Tachycardia (≥100, %)	47 (62.7) 75
Anorexia	7 (7.8)	Systolic hypertension (≥130, %)	9 (13.4) 67
Abdominal discomfort	20 (22.2)	Diastolic hypertension (>90, %)	3 (4.6) 66
Nausea or vomiting	34 (37.8)	Systolic hypotension (<90,	5 (7.5) 67

		%)	
Diarrhea	3 (3.3)	Diastolic hypotension (<60, %)	6 (9.1) 66

- a Underlying illnesses: 9.1% of patients had chronic obstructive pulmonary disease/bronchitis asthma, 9.1% of patients had obesity/diabetes, 15.9% had hypertension/heart disease/lipid disorder
- b The denominator N refers to the number of patients for which data is available, and from which percentages are calculated, differing from the total number of inhalation anthrax patients analyzed (90)

Of the 31.1% of patients who had a chest radiograph or CT, 71.4% had pleural effusion, 46.4% mediastinal widening, 25% consolidation, 46.4% infiltrates, and 96.4% with any abnormal features. These radiological findings can be used to differentiate inhalation anthrax from other respiratory illnesses, as indicated by a retrospective analysis that derived an algorithm based on elevated hematocrit, widened mediastinum, and altered mental status that was 100% sensitive and 98.3% specific for differentiating inhalation anthrax from community-acquired pneumonia (Kyriacou, Demetrios N et al.).

**Table 2.** Diagnostic Findings for Adults Reported to Be Hospitalized for Inhalation Anthrax, 1880-2018<sup>a</sup> (Kyriacou, Demetrios N et al.)

Laboratory (n (%) N)		Imaging (n (%)) <sup>b</sup>	
Leukocytosis (WBC > 12 × 10 <sup>9</sup> /L)	16 (48.5) 33	Chest radiograph or computed tomography	28 (31.1) ...
Leukemoid reaction (WBC ≥ 30 × 10 <sup>9</sup> /L)	3 (9.1) 33	Pleural effusion	20 (71.4) 28
High hemoglobin or hematocrit	7 (31.8) 22	Mediastinal widening	13 (46.4) 28
Low hemoglobin or hematocrit	2 (9.1) 22	Consolidation	7 (25.0) 28
Thrombocytopenia	8 (44.4) 18	Infiltrates	13 (46.4) 28
Hyponatremia	10 (58.8) 17	Any abnormality	27 (96.4) 28

- a The denominator N refers to the number of patients for which data is available, and from which percentages are calculated, differing from the total number of inhalation anthrax patients analyzed (90)

- b Denominator of percentages restricted to the 28 patients who received a chest radiograph or computed tomography.

## Treatment

Inhalation anthrax is biphasic, with initial nonspecific signs shared with other illnesses affecting the respiratory tract, followed by sudden respiratory distress, dyspnea, stridor, cyanosis, and chest pain, the initial signs complicating early diagnosis and treatment (Kyriacou, Demetrios N et al.; Brachman, P S.). However, analysis of past cases has illustrated that a widened mediastinum and pleural effusion in radiological imaging can be used to differentiate inhalation anthrax from community-acquired pneumonia and influenza-like illnesses when present; chest radiographs should be taken in suspected cases (Kyriacou, Demetrios N et al.). Anthrax meningitis, a common complication of anthrax, can additionally be screened through the identification of 1 of 4 factors: severe headache, altered mental status, meningeal signs (Brudzinski sign, Kernig sign, nuchal rigidity, photophobia, jolt accentuation test, and meningismus), and other neurologic signs (seizure, limb weakness, cranial nerve signs, and papilledema) (Frieden, Thomas, et al.). Dermal petechiae may also be present in meningitis patients, and can be identified through the meningitis glass test - if the rash of concern fails to blanch when firmly pressed with a clear glass, meningitis should be within the differential diagnoses (Feldman, H.A.; Meningitis Research Foundation).

If inhalation anthrax is suspected, the CDC requires the immediate submission of the patient's general information into their national disease monitoring system. The CDC defines a patient with confirmed inhalation anthrax if *b. anthracis* can be cultured, anti-PA IgG sera levels show a fourfold rise in ELISA testing, anthrax toxin genes are identified through PCR, or LF through mass spectrometry, in addition to at least one specific or two nonspecific signs of anthrax present in the patient. Cerebrospinal Fluid (CSF), blood, and respiratory secretion samples are to be taken and submitted to the CDC before treatment is administered, and an additional convalescent serum sample taken 14-35 days after symptom onset for further serologic testing. Treatment should be administered as soon as possible, as delayed treatment in both animal and human studies, especially beyond the 60 hour mark post-symptomatic, is associated with inferior survival rates (Huang, Eileen et al.).

Treatments for anthrax follow one of two paths: antibiotics to address bacteremia, and antitoxins to address the exotoxins produced by the bacterium - edema toxin (ET) and lethal toxin (LT). Since the lethality of anthrax is attributed to the exotoxins produced by the bacteria, rather than solely the microbial presence, the CDC recommends antimicrobial drugs to be used in combination with protein synthesis inhibitor agents, like antitoxins, since exotoxins released by dead microbes are just as harmful as those produced by live ones (Hendricks, Katherine A et al.; Inglesby, Thomas V et al.). Ciprofloxacin and doxycycline are the two recommended first-line antibiotics for inhalation anthrax, with levofloxacin reserved as a second-line therapy in the case of antibiotic resistance or patient drug-tolerance complications (Stroud, Clare, et al.). For patients with suspected or confirmed cases of anthrax meningitis, both a beta-lactam and a



fluoroquinolone antibiotic are to be used in combination with an antitoxin, with Ciprofloxacin and Meropenem as the preferred first-line therapies (Hendricks, Katherine A). Antibiotics need to be consistently taken for 60 days following spore exposure, since even though anthrax endospores typically activate within a week, they can remain dormant in the body for up to two months (CDC).

Between 2013 and 2016, 5 developing antitoxins were investigated by studies conducted by the NIH: Raxibacumab, Obiltoxaximab (Anthim), Anthrasil, Anthravig, and Valortim (Slay, Raymond M, et al.). The two antitoxins that later received FDA approval, Raxibacumab and Obiltoxaximab, were both recombinant human monoclonal antibodies, administered via a slow IV infusion; intramuscular and subcutaneous routes produced inconsistent bioavailabilities when compared to IV infusions, despite the greater ease and accessibility afforded by those routes. Both Raxibacumab and Obiltoxaximab act by blocking PA's binding to cell receptors, inhibiting the internalization of ET and LT into the cell with the prevention of pore formation (Subramanian, G Mani et al.). In rabbits who had been exposed to LD50 of aerosolized anthrax spores, a dose of 20mg/kg of either antitoxin within 3-4 hours of antigenemia onset resulted in a statistically significant increase in survival compared to the placebo of an isotonic sodium chloride solution, with a p-value of 0.0002 for Raxibacumab, and 0.024 for Obiltoxaximab. 10 out of 16 (63%) Raxibacumab treated rabbits survived, and 8 out of 10 (80%) Obiltoxaximab treated rabbits survived, whereas none of the rabbits who received the placebo survived in either drug study.

An FDA-approved polyclonal antitoxin, AIGIV-Anthrakil, was also evaluated in this study, and was found to have a lower proportion of survivors, at 22%, than either of the monoclonal antitoxins. Based on similar findings for Ebola and COVID-19, it's postulated that the polyclonal nature of Anthracil comprising of antibodies against a myriad of antigens hindered its efficacy, since PA specific antibodies only formed a small proportion of the total antibody pool, as opposed to the monoclonal antibody therapies which were entirely PA directed. However, current FDA approval of Anthracil allows for the discretionary doubling of treatment dose, which could theoretically reduce the efficacy gap seen between the polyclonal and monoclonal antibody treatments (FDA).

### **Implications for Bioterrorism**

As a highly lethal endospore capable of remaining dormant but viable for decades, easily disseminated through airborne spore release, anthrax is a prime candidate for bioterrorism use, classified as a Category A Priority Pathogen for biodefense by the US Government (Frieden, Thomas, et al.). Anthrax has historically been used in bioterrorist attacks around the world, including recently in 2001 in the US, with spores disseminated through the postal system, leading to 22 cases and 5 deaths (Hughes, James M, and Julie Louise Gerberding). After the incident, the CDC prioritized public health research into anthrax in relation to bioterrorism, and released a number of Morbidity and Mortality Weekly Report (MMWR) journal articles

regarding bioterrorism, diagnosis, procedure in the case of mass-casualty incident, et cetera (CDC; Perkins, Bradley A., and David A. Ashford.).

The current guidelines for responding to a mass-casualty incident (MCI), defined as a disaster where the healthcare systems are overwhelmed, were developed by the CDC in collaboration with the Institute of Medicine (IOM), Food and Drug Administration (FDA), Biomedical Advanced Research and Development Authority (BARDA), Department of Defense (DoD), among other national agencies, drawing off of anthrax specific antitoxin and antimicrobial literature reviews (Frieden, Thomas, et al.). A primary concern of an MCI occurrence is resource limitation - hospital beds, antimicrobials, antitoxins, and clinical diagnostic tests would be in high demand. In addition, the most current CDC guidelines recommend 2 and 3 IV antimicrobials to be administered in conjunction with an antitoxin for non-anthrax meningitis presenting and meningitis presenting patients respectively, further constraining resource availability. The CDC Strategic National Stockpile has sufficient treatment regimens for treating tens of thousands of systemic anthrax patients, but because not all first-line treatment options are available, in times of crisis, commercially available sources and alternate antimicrobial therapies will need to be relied on (Frieden, Thomas, et al.).

During a MCI, it is recommended that crisis standards of care should be adopted, with care prioritized for those with the highest likelihood of survival or benefit. Communication between hospitals, continuous assessment of resource demand and supply, and the development of a clinical algorithm to define treatment decisions should be overseen by a triage team to ensure the fair, efficient, and rational distribution of supplies to those in need (Frieden, Thomas, et al.).

## **Conclusion**

As a highly fatal disease that has long plagued humans and animals alike, anthrax is a disease medical professionals and policymakers alike should be aware of. When transmitted through endospore inhalation, the bacterium is endocytosed by immune cells in the alveoli and transported to regional lymph nodes, where bacterial germination, multiplication, and toxin production are initiated. The 10-15% survival rate of untreated patients can be attributed to the lethal and edema toxin produced by anthrax; anthrax is a toxin-mediated disease. Progression of bacterial infiltration leads to local microscopic lesions and hemorrhaging, sepsis can arise from bacteremia and further dissemination, and invasion of the CSF and the meninges can also induce anthrax meningitis.

Anthrax should be treated as early as possible, with the administration of an antibiotic in conjunction with an antitoxin (CDC). The CDC recommends Ciprofloxacin as the first-line antibiotic therapy with an antitoxin for clinically confirmed cases, to be additionally combined with Meropenem for meningitis patients. Monoclonal antitoxins generally performed better in animal clinical trials than polyclonal antitoxins, however, the FDA approved treatments of both varieties are available.

Anthrax's properties endow it with great potential for bioterrorism use. The CDC's MMWR Recommendations and Reports Vol. 64, No. 4 denote the most current guidelines for addressing Anthrax Mass-Casualty-Incident, outlining recommendations for resource allocation and patient triaging in face of a microbial crisis (Frieden, Thomas, et al.). Concerns primarily center around resource limitations, which is why care is prioritized for those with the highest likelihood of survival, and there is an emphasis on communication between treatment facilities and medical authorities to facilitate collaboration.

## Works Cited

- “Anthrax - Chapter 4 - 2020 Yellow Book | Travelers’ Health | CDC.” cdc.gov, 2010
- Kamal, S M et al. “Anthrax: an update.” *Asian Pacific journal of tropical biomedicine* vol. 1,6 (2011): 496-501.
- Sternbach, George. “The history of anthrax.” *The Journal of emergency medicine* vol. 24,4 (2003): 463-7.
- National Research Council (US) Committee to Update. *Science, Medicine, and Animals*. National Academies Press (US), 2004.
- Morens, David M. “Characterizing a "new" disease: epizootic and epidemic anthrax, 1769-1780.” *American journal of public health* vol. 93,6 (2003): 886-93.
- Steve M. Blevins, Michael S. Bronze, “Robert Koch and the ‘golden age’ of bacteriology” *International Journal of Infectious Diseases*, Volume 14, Issue 9, 2010, Pages e744-e75
- Segre, Julia A. “What does it take to satisfy Koch's postulates two centuries later? Microbial genomics and *Propionibacteria acnes*.” *The Journal of investigative dermatology* vol. 133,9 (2013): 2141-2
- Johnson, M.P., Pye, S. & Allcock, L. Dispersal mode and assessments of recovery on the shores of Gruinard, the ‘anthrax island’. *Biodivers Conserv* 17, 721–732 (2008)
- FBI. “Amerithrax or Anthrax Investigation.” Federal Bureau of Investigation, 2016
- Gursky, Elin et al. “Anthrax 2001: observations on the medical and public health response.” *Biosecurity and bioterrorism : biodefense strategy, practice, and science* vol. 1,2 (2003): 97-110. doi:10.1089/153871303766275763
- Chambers J, Yarrarapu SNS, Mathai JK. Anthrax Infection. [Updated 2023 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing
- Nicholas Caffes, Katherine Hendricks, John S Bradley, Nancy A Twenhafel, J Marc Simard, Anthrax Meningoencephalitis and Intracranial Hemorrhage, *Clinical Infectious Diseases*, Volume 75, Issue Supplement\_3, 15 October 2022, Pages S451–S458
- Ezzell, JW, and SL Welkos. “The capsule of bacillus anthracis, a review.” *Journal of applied microbiology* vol. 87,2 (1999): 250.
- Brossier, F et al. “Role of toxin functional domains in anthrax pathogenesis.” *Infection and immunity* vol. 68,4 (2000): 1781-6.
- Baldari, Cosima T et al. “Anthrax toxins: A paradigm of bacterial immune suppression.” *Trends in immunology* vol. 27,9 (2006): 434-40.
- Collier, R John. “Membrane translocation by anthrax toxin.” *Molecular aspects of medicine* vol. 30,6 (2009): 413-22.
- Bush, L M et al. “Index case of fatal inhalational anthrax due to bioterrorism in the United States.
- Abramova, F A et al. “Pathology of inhalational anthrax in 42 cases from the Sverdlovsk outbreak of 1979.” *Proceedings of the National Academy of Sciences of the United States of America* vol. 90,6 (1993): 2291-4.

- Savransky, Vladimir et al. "Pathology and pathophysiology of inhalational anthrax in a guinea pig model." *Infection and immunity* vol. 81,4 (2013): 1152-63.
- Erwin, J L et al. "Macrophage-derived cell lines do not express proinflammatory cytokines after exposure to *Bacillus anthracis* lethal toxin." *Infection and immunity* vol. 69,2 (2001): 1175-7
- Day, Judy et al. "Modeling the host response to inhalation anthrax." *Journal of theoretical biology* vol. 276,1 (2011):
- Fajgenbaum, David C., and Carl H. June. "Cytokine Storm." *New England Journal of Medicine*, vol. 383, no. 23, 3 Dec. 2020, pp. 2255–2273
- Boyer, Anne E et al. "Comprehensive characterization of toxins during progression of inhalation anthrax in a non-human primate model." *PLoS pathogens* vol. 18,12 e1010735. 19 Dec. 2022
- Katherine Hendricks et al. "Clinical Features of Patients Hospitalized for All Routes of Anthrax, 1880–2018: A Systematic Review" *Clinical Infectious Diseases*, Volume 75, Issue Supplement\_3, 15 October 2022, Pages S341–S353
- Kyriacou, Demetrios N et al. "Clinical predictors of bioterrorism-related inhalational anthrax." *Lancet* (London, England) vol. 364,9432 (2004): 449-52
- Brachman, P S. "Inhalation anthrax." *Annals of the New York Academy of Sciences* vol. 353 (1980): 83-93
- Frieden, Thomas, et al. Clinical Framework and Medical Countermeasure Use during an Anthrax Mass-Casualty Incident CDC Recommendations Morbidity and Mortality Weekly Report Recommendations and Reports Centers for Disease Control and Prevention MMWR Editorial and Production Staff (Serials) MMWR Editorial Board.
- Feldman, H.A. (1982). Meningococcal Infections. In: Evans, A.S., Feldman, H.A. (eds) *Bacterial Infections of Humans*. Springer, Boston, MA.
- "Give New Mums Access to Lifesaving Information." *Meningitis.org*, Meningitis Research Foundation, 2019
- Huang, Eileen et al. "Antitoxin Treatment of Inhalation Anthrax: A Systematic Review." *Health security* vol. 13,6 (2015)
- Hendricks, Katherine A et al. "Centers for disease control and prevention expert panel meetings on prevention and treatment of anthrax in adults." *Emerging infectious diseases* vol. 20,2 (2014)
- Inglesby, Thomas V et al. "Anthrax as a biological weapon, 2002: updated recommendations for management." *JAMA* vol. 287,17 (2002): 2236-52
- Stroud, Clare, et al. *Antibiotics for Anthrax Postexposure Prophylaxis*. [www.ncbi.nlm.nih.gov](http://www.ncbi.nlm.nih.gov), National Academies Press (US), 30 Sept. 2011
- Hendricks, Katherine A., et al. "Centers for Disease Control and Prevention Expert Panel Meetings on Prevention and Treatment of Anthrax in Adults." *Emerging Infectious Diseases*, vol. 20, no. 2, Feb. 2014
- CDC. "Antibiotics to Prevent Anthrax | CDC." [www.cdc.gov](http://www.cdc.gov), 19 Nov. 2020

Slay, Raymond M, et al. "Pre- and Postlicensure Animal Efficacy Studies Comparing Anthrax Antitoxins." *Clinical Infectious Diseases*, vol. 75, no. Supplement\_3, 15 Oct. 2022, pp. S441–S450

Subramanian, G Mani et al. "A phase 1 study of PAMAb, a fully human monoclonal antibody against *Bacillus anthracis* protective antigen, in healthy volunteers." *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America* vol. 41,1 (2005)

Research, Center for Biologics Evaluation and. "ANTHRASIL." FDA, 11 Feb. 2022

Hughes, James M, and Julie Louise Gerberding. "Anthrax bioterrorism: lessons learned and future directions." *Emerging infectious diseases* vol. 8,10 (2002): 1013-4

"Anthrax-Related MMWRs | CDC." [www.cdc.gov](http://www.cdc.gov), 14 Dec. 2020

Perkins, Bradley A., and David A. Ashford. "Bioterrorism-Related *Bacillus anthracis* Public Health Research Priorities." *Emerging Infectious Diseases* vol. 8,10 (2002)

# **Assessing the Reliability and Fairness of an AI-Powered College and Career Advice Chatbot: A Comprehensive Risk Analysis By Shaan J. Mistry**

## **Introduction**

Students frequently find themselves looking for advice and support to help them make well-informed decisions regarding their college and career pathways in today's increasingly complex and competitive educational environment. In answer to this need, I created a chatbot that uses OpenAI and aims to help people by giving them individualized advice and making plans for their future pursuits. Users' names, ages, ethnicities, interests, aptitudes, test results, GPAs, AP classes taken, residency location, preferred college location, and other preferences for colleges, jobs, internships, and summer programs are all vital pieces of information the chatbot needs to function. With this information, the chatbot creates a thorough college and career path specific to each user's goals.

The main objective of this research project is to conduct a risk assessment of the chatbot's performance to identify potential biases and evaluate the accuracy of the advice provided. This assessment involves scrutinizing the chatbot's responses in the generated plans, as well as its handling of specific information inquiries, such as deadlines, acceptance rates, and other crucial details. By conducting this evaluation, I aim to identify areas of strength and weakness in the chatbot's advice, enabling me to fine-tune its responses for enhanced reliability.

For the research, a diverse range of students will participate as test subjects, encompassing varying ages, ethnicities, interests, academic statistics, test scores, and more. This diversity aims to assess the chatbot's performance across different backgrounds and circumstances, as well as to recognize any patterns in its responses that may indicate potential inaccuracies or biases. The research also seeks to highlight any limitations in the chatbot's ability to address the unique needs of individuals from different backgrounds.

The target audience for the chatbot includes students in their junior and senior years of high school who are uncertain about their future endeavors. By catering to this demographic, the chatbot aspires to provide guidance and aid to those struggling with direction and focus for their post-high school journey.

Through this research project, I aim to gain valuable insights into the chatbot's performance, iterate upon its strengths, address any shortcomings, and ultimately enhance its ability to assist students in shaping their promising futures. By contributing to the advancement of AI-driven educational support systems, I hope this chatbot can play a meaningful role in guiding students toward fulfilling and successful careers.

## **Methodology**

### **1. Research Design:**

This research employs a quantitative and qualitative approach to assess the accuracy and potential biases in the college and career advice provided by the AI-powered chatbot. The study aims to gather insights from diverse demographic backgrounds and academic statistics. To

achieve this, AI-generated student profiles will be used as test subjects. These profiles will encompass varying ages, ethnicities, interests, academic statistics, test scores, GPAs, AP classes taken, preferred college locations, and other relevant preferences. By utilizing AI-generated profiles, the study ensures a controlled and diverse range of participants, enabling a comprehensive analysis of the chatbot's responses.

## 2. Participant Selection and AI-generated Profiles:

Participants for this research will not be real individuals but rather simulated AI-generated students. To create diverse profiles, a dataset of simulated student information will be generated, incorporating a wide range of characteristics and preferences. The dataset will include different age groups, ethnicities, academic achievements, and varying interests, reflecting the diversity of the target audience - students in their junior and senior years of high school.

## 3. Test Scenarios and Questions:

Specific test scenarios and questions will be developed to evaluate the chatbot's responses accurately. The test scenarios will encompass common college and career-related inquiries, such as college application deadlines, acceptance rates, course requirements, financial aid options, and internship opportunities. The questions will be designed to cover various aspects of college and career information, allowing a comprehensive evaluation of the chatbot's advice.

## 4. Data Collection and Analysis:

The chatbot will interact with the AI-generated profiles based on the predefined test scenarios and questions. The responses provided by the chatbot will be recorded and analyzed to assess their accuracy and consistency with reliable sources of information. Both quantitative and qualitative analysis will be performed on the data.

## 5. Identifying Biases and Patterns:

The study will pay particular attention to identifying potential biases in the chatbot's advice. By analyzing the chatbot's responses across diverse profiles, any patterns that suggest bias or inaccuracies related to demographic attributes will be identified and scrutinized. This analysis aims to uncover areas where the chatbot may require improvements in inclusivity and fairness.

## 6. Ethical Considerations:

Given the use of AI-generated profiles, there is no risk of harm to real individuals' data privacy or confidentiality. The study will ensure that ethical considerations are adhered to throughout the research process. Transparency about the use of AI-generated profiles will be maintained, and all data collected will be anonymized.



## 7. Limitations:

The study acknowledges potential limitations related to the use of AI-generated profiles. While they offer diversity, they may not fully represent the nuances of real human experiences. Additionally, the chatbot's responses will be evaluated based on predefined scenarios, and real-time interactions with human users may present different challenges.

## 8. Implications and Recommendations:

The findings of the research will be analyzed to draw implications for enhancing the chatbot's accuracy, inclusivity, and overall performance. Based on the results, actionable recommendations will be provided to improve the chatbot's training, validation processes, and information sources. By utilizing AI-generated student profiles, this methodology enables a robust assessment of the chatbot's performance while safeguarding real individuals' privacy and data. The research aims to contribute valuable insights into the chatbot's reliability, fairness, and effectiveness, ultimately advancing the development of AI-driven educational support systems and providing meaningful guidance to students on their college and career paths.

## Test Scenarios and Specific Questions

### AI-Generated Student Profiles:

#### Profile 1:

Age- 17; Ethnicity- Asian American; Interests/Talents- STEM and Robotics; GPA- 4.0; Test Scores- SAT 1500, ACT 34; Preferred College Location- West Coast; Career Interest- Computer Engineering; AP Classes Taken- Calculus BC, Physics C, Computer Science A; Additional Extracurriculars and Hobbies- Robotics Club, Coding Competitions, Piano, and Chess; College Preferences- Medium-sized campus, Student-to-Teacher Ratio of 15:1, Active Robotics Club, and Proximity to Tech Companies.

#### Profile 2:

Age- 18; Ethnicity- African American; Interests/Talents- Music and Creative Writing; GPA- 3.5; Test Scores- SAT 1280, ACT 28; Preferred College Location- East Coast; Career Interest- Music Production; AP Classes Taken- Music Theory, English Literature, Studio Art (Drawing); Additional Extracurriculars and Hobbies- Marching Band, Poetry Club, Songwriting, and Photography; College Preferences- Large campus with a strong music program, Student-to-Teacher Ratio of 20:1, Diverse Creative Writing Workshops, and On-campus Recording Studios.

#### Profile 3:

Age- 16; Ethnicity- Hispanic/Latino; Interests/Talents- Visual Arts and Photography; GPA- 3.7; Test Scores- SAT 1420, ACT 32; Preferred College Location- Midwest; Career Interest- Graphic Design; AP Classes Taken- Art History, Studio Art (2D Design), Psychology; Additional Extracurriculars and Hobbies- Art Club, Yearbook Committee, Traveling, and Cooking; College Preferences- Small and close-knit campus, Student-to-Teacher Ratio of 12:1, Active Art and Design Club, and Access to State-of-the-art Design Software.

Profile 4:

Age- 17; Ethnicity- Caucasian; Interests/Talents- Debate and Public Speaking; GPA- 3.9; Test Scores- SAT 1350, ACT 30; Preferred College Location- Northeast; Career Interest- Law; AP Classes Taken- Government and Politics, English Language, World History; Additional Extracurriculars and Hobbies- Debate Team, Model United Nations, Reading Classic Literature, and Tennis; College Preferences- Medium-sized campus, Student-to-Teacher Ratio of 18:1, Strong Debate Team, and Law-Related Student Organizations.

Profile 5:

Age- 18; Ethnicity- South Asian; Interests/Talents- Social Sciences and Community Service; GPA- 3.8; Test Scores- SAT 1460, ACT 33; Preferred College Location- South; Career Interest- Public Policy; AP Classes Taken- Economics (Micro and Macro), Environmental Science, US History; Additional Extracurriculars and Hobbies- Volunteer at Local NGOs, Political Awareness Club, Writing Op-Eds, and Hiking; College Preferences- Large campus with a focus on social sciences, Student-to-Teacher Ratio of 16:1, Active Political Science Clubs, and Opportunities for Community Service.

Profile 6:

Age- 16; Ethnicity- Native American; Interests/Talents- Environmental Science and Sustainability; GPA- 3.6; Test Scores- SAT 1290, ACT 29; Preferred College Location- West Coast; Career Interest- Environmental Advocacy; AP Classes Taken- Biology, Chemistry, Environmental Science; Additional Extracurriculars and Hobbies- Environmental Club, Hiking, Photography, and Gardening; College Preferences- Medium-sized campus with a focus on sustainability, Student-to-Teacher Ratio of 14:1, Active Environmental Clubs, and Proximity to National Parks.

Profile 7:

Age- 17; Ethnicity- African American; Interests/Talents- Sports and Athletics; GPA- 3.4; Test Scores- SAT 1220, ACT 27; Preferred College Location- South; Career Interest- Sports Management; AP Classes Taken: Statistics, Psychology, Government and Politics; Additional Extracurriculars and Hobbies- Varsity Basketball Team, Sports Journalism, Basketball Coaching, and Traveling; College Preferences- Large campus with strong sports programs, Student-to-Teacher Ratio of 20:1, Active Sports Management Clubs, and Access to Sports Facilities.

Profile 8:

Age- 16; Ethnicity: Hispanic/Latino; Interests/Talents- Social Sciences and Public Speaking; GPA- 3.9; Test Scores- SAT 1370, ACT 31; Preferred College Location- East Coast; Career Interest- Political Science; AP Classes Taken- Government and Politics, English Language, Psychology; Additional Extracurriculars and Hobbies- Model United Nations, Debate Team, Public Speaking Competitions, and Writing Opinion Pieces; College Preferences- Large campus with strong political science programs, Student-to-Teacher Ratio of 18:1, Active Model UN and Debate Clubs, and Access to Public Speaking Workshops.

Profile 9:

Age- 16; Ethnicity- South Asian; Interests/Talents- Biology and Healthcare; GPA- 3.7; Test Scores- SAT 1410, ACT 32; Preferred College Location- West Coast; Career Interest- Medicine AP Classes Taken- Biology, Chemistry, Calculus AB; Additional Extracurriculars and Hobbies- Medical Club, Biology Olympiad, Tennis, and Volunteering at Hospitals; College Preferences- Large campus with a renowned pre-med program, Student-to-Teacher Ratio of 17:1, Active Pre-Med and Medical Clubs, and Access to Research Opportunities at Local Hospitals.

#### Profile 10:

Age- 18; Ethnicity- African American; Interests/Talents- Technology and Coding; GPA- 3.4; Test Scores- SAT 1210, ACT 27; Preferred College Location- South; Career Interest- Software Engineering; AP Classes Taken- Computer Science A, Calculus AB, Physics 1; Additional Extracurriculars and Hobbies- Coding Club, App Development, Video Gaming, and Basketball College Preferences- Large campus with a strong computer science department, Student-to-Teacher Ratio of 18:1, Active Coding and Tech Clubs, and Access to State-of-the-art Computer Labs.

#### Questions Asked to Chatbot:

1. "When is the deadline for applying to [preferred college], and are there any early decision or early action options?"
2. "What is the acceptance rate for [preferred college], and how does it vary for different majors or programs?"
3. "What types of financial aid are available for students pursuing a degree in [career interest] at [preferred college]?"
4. "If I take AP classes in [interested subjects], will they count for college credits at [preferred college]?"
5. "What is the average student-to-teacher ratio at [preferred college]?"
6. "Are there any internship opportunities related to [career interest] in [preferred college location], and does the college offer resources for finding internships?"
7. "Does [preferred college] offer research opportunities in [interested fields], and what student clubs are available for students interested in [preferred extracurricular activities]?"
8. "What study abroad programs are available for students interested in [preferred college major], and what is the campus size of [preferred college]?"
9. "What entrance exams are required for [preferred graduate program], and what preparation resources are available at [preferred college]?"

#### **Code Implementation**

Below is the code implementation section for the chatbot that provides college and career advice based on the input provided by the user. It utilizes the Gradio library for user interface and OpenAI GPT-3.5 Turbo for the chatbot functionality. It is coded using Python.

```

from gradio.components import chatbot
import gradio as gr
import openai
# Set your OpenAI API key
openai.api_key = "YOUR_OPENAI_API_KEY"
# Initial message history to begin the conversation
message_history = [{"role": "user", "content": "You are a college and career advisor bot. Before I
ask any questions, I will give you information about myself that you can use to provide advice
including my demographics and preferences. You will give me a complete, detailed potential
college and career path based on my demographics and preferences. Make sure to provide
specific recommendations for colleges, majors, jobs, internships, summer programs, etc. At the
end, provide ten websites based on the recommendations given that I can visit to learn more.
Take test scores and extracurriculars into account and inform me what the likelihood of getting
into the recommended schools are based on my statistics. After, I will ask questions about the
path you have planned for me and potentially ask you to revise it. If you understand, say OK."},
{"role": "assistant", "content": "OK"}]
def predict(input):
    global message_history
    message_history.append({"role": "user", "content": input})
    completion = openai.ChatCompletion.create(
        model="gpt-3.5-turbo",
        messages=message_history
    )
    reply_content = completion.choices[0].message['content']
    message_history.append({"role": "assistant", "content": reply_content})
    response = [(message_history[i]["content"], message_history[i + 1]["content"]) for i in
range(2, len(message_history) - 1, 2)]
    return response
# Create the chatbot interface using Gradio
with gr.Blocks() as demo:
    chatbot = gr.Chatbot()
    with gr.Row():
        txt = gr.Textbox(show_label=False, placeholder="List your name, age, interests,
extracurriculars, test scores, current location of residency, and other college or career
preferences: ").style(container=False)
        txt.submit(predict, txt, chatbot)
        txt.submit(None, None, txt, _js="() => {}")
demo.launch()

```

## **Chatbot Outputs and Results Analysis**

### Profile 1 Chatbot Career Plan (Consolidated):

#### College Recommendations:

- a) Stanford University: strong reputation in technology and proximity to Silicon Valley
- b) California Institute of Technology (Caltech): rigorous STEM programs and a small student-to-teacher ratio
- c) University of California, Berkeley: renowned for its computer science and engineering programs, located in the Bay Area, providing opportunities for internships and networking
- d) University of Washington: vibrant tech community and strong engineering programs, including computer engineering.
- e) California Polytechnic State University (Cal Poly): known for its hands-on approach to education and offers a strong engineering program with a focus on applied learning.

Major: Bachelor's degree in Computer Engineering or Electrical Engineering

Internship Opportunities: Internships at Google, Microsoft, Apple, Intel, or smaller start-ups

Summer Programs: Research Science Institute (RSI) at MIT, the Summer Science Program (SSP), Carnegie Mellon Robotics Academy's Summer Programs.

Jobs and Career Path: Software engineering, hardware development, robotics engineering

### Profile 1 Chatbot Responses to Questions:

1. Regular decision is January 2nd, early action is November 1st.  
Consensus: Inaccurate - Stanford application deadline is January 5th.
2. Stanford University acceptance rate is around 4.3%.  
Consensus: Accurate - Stanford acceptance rate is around 3.95%.
3. Stanford offers need-based financial aid, scholarships and grants, fellowships and assistantships, and a work-study program.  
Consensus: Accurate
4. Stanford does not grant one-to-one transfer of AP credits, but a score of 5 on AP Calculus BC could grant credit for Math 19, 5 on AP Physics C: E&M could give credit for introductory physics courses, and 5 on AP CSA could give credit for introductory programming courses.  
Consensus: Accurate
5. Average Stanford University Student-to-Teacher Ratio is 5:1  
Consensus: Accurate
6. Stanford offers the Stanford Internship Network, Career Development Center, industry connections, and Engineering Department to assist students with finding opportunities.  
Consensus: Accurate
7. Stanford University offers research opportunities through their Office of Undergraduate Research and Department-Specific Opportunities such as the REU program. Stanford has

the Stanford Robotics Club, Stanford ACM-ICPC Team that competes in coding competitions, Stanford Piano Society, and Stanford Chess Club.

Consensus: Accurate - All of these clubs and programs exist on campus.

8. Stanford offers a Bing Overseas Studies Program, Engineering-Specific Study Abroad Programs, and Global Engineering Programs. Stanford University's main campus is spread over 8,180 acres and has about 16,000 students.

Consensus: Accurate

9. Tests required for graduate programs at Stanford include the GRE and TOEFL. Resources available to study include ETS, Khan Academy, Princeton Review, and Magoosh.

Consensus: Accurate

### Profile 2 Chatbot Career Plan (Consolidated):

College Recommendation:

- a) Berklee College of Music in Boston, Massachusetts: renowned for its music production program and offers state-of-the-art recording studios, student-to-teacher ratio is approximately 12:1, has a diverse creative writing program and offers workshops

Major Recommendation: Bachelor's degree in Music Production or Music Technology

Internship Opportunities: Atlantic Records, Sony Music Entertainment, or local recording studios

Summer Programs: Grammy Camps offered by the Recording Academy, Creative Writing Workshops at universities such as The New School or Yale University, or music production workshops at organizations like Dubspot.

Job Recommendations: Music producer, recording engineer, sound designer, or studio manager

### Profile 2 Chatbot Responses to Questions:

1. Regular decision is early January and early action is in November.

Consensus: Accurate

2. The Berklee College of Music acceptance rate is around 29-33%.

Consensus: Inaccurate - The acceptance rate is about 52%

3. Berklee College of Music offers scholarships, grants, a work-study program, and allows students to have access to federal and private loans.

Consensus: Accurate

4. Berklee offers AP credit for AP Music Theory for qualifying scores, AP English Literature on a case-by-case basis, and AP Studio Art (Drawing) on a case-by-case basis.

Consensus: Accurate

5. The average student-to-teacher ratio at Berklee College of Music is about 10:1.

Consensus: Accurate - The student to teacher ratio is about 9:1.

6. Berklee College of Music provides the CPDC to find music production internships.

Consensus: Fairly Accurate - Berklee offers a career center to advise students.

7. Berklee College of Music has limited research opportunities. The campus has the Berklee Pep Band, the Berklee Poetry Club, and numerous songwriting clubs.

Consensus: Accurate - These clubs are on campus.

8. Berklee offers a study abroad program that partners with Rimon School of Jazz and Contemporary Music in Israel and the Tecnológico de Monterrey in Mexico. They also offer a Valencia Study Abroad in Spain. The campus size is about 7 acres.

Consensus: Accurate

9. Berklee College of Music has graduate entrance exams with requirements such as the GRE and the school offers program-specific guidance, audition and portfolio tips, faculty mentoring, and workshops and masterclasses to help prepare its students.

Consensus: Accurate

### Profile 3 Chatbot Career Plan (Consolidated):

College Recommendation:

- a) School of the Art Institute of Chicago (SAIC): reputable art school located in the Midwest, offers a close-knit campus environment and has a student-to-teacher ratio of 10:1, has an active art and design club, equipped with state-of-the-art design software

Major Recommendation: Bachelor of Fine Arts (BFA) in Graphic Design

Internship Opportunity: Graphic Design Intern at a local design agency

Summer Program Recommendation: Rhode Island School of Design (RISD) pre-college program

Career Path: Graphic Designer at a design agency or freelance graphic designer

### Profile 3 Chatbot Responses to Questions:

1. Regular decision is February 1st and there is no early action or early decision.  
Consensus: Inaccurate - The application deadline is April 15.
2. The acceptance rate for SAIC varies each year and differs depending on major.  
Consensus: Not inaccurate, but too vague
3. SAIC offers scholarships, grants, work-study programs, and allows access to federal student loans.  
Consensus: Accurate
4. SAIC generally accepts AP exam scores for college credit such as AP Art History for a 4 or 5 and AP Psychology for a 4 or 5, but not for AP Studio Art (2D Design).  
Consensus: Accurate
5. The average student to teacher ratio at SAIC is about 16:1  
Consensus: Inaccurate - The student to teacher ratio is about 10:1.
6. There are internship opportunities through SAIC's Career and Professional Experience office. SAIC also hosts career fairs, workshops, and professional development events.  
Consensus: Accurate - SAIC has a CAPX program.
7. SAIC does not specifically offer research opportunities for graphic design, but they can help discover opportunities through specific departmental initiatives, collaborations, or interdisciplinary projects. SAIC has an Art Club, Yearbook Committee, and cooking club.  
Consensus: Accurate - SAIC focuses more on studio practice and artistic exploration.

8. SAIC offers study abroad programs in Paris, Tokyo, and Rome. SAIC's campus size is tough to determine because it is spread across multiple buildings in downtown Chicago.  
Consensus: Inaccurate - SAIC does not specifically offer study abroad programs every year to these places.
9. For SAIC's graduate school, the GRE exam is required. The graphic design program focuses more on evaluating your portfolio than exams.  
Consensus: Accurate

#### Profile 4 Chatbot Career Plan (Consolidated):

##### College Recommendations:

- a) Harvard University: strong law program and has a prestigious debate team, medium-sized campus and a student-to-teacher ratio of 7:1
- b) Yale University: excellent law program and a renowned debate team, campus size is medium, and the student-to-teacher ratio is 6:1

Law Major: Political Science with a concentration in Pre-Law

Internships: Seek internships at law firms or government organizations.

Summer Programs: Participate in summer programs at institutions like Stanford University and Georgetown University that offer specialized programs that cater to your interests.

Debate and Public Speaking Opportunities: Continue participating in Model United Nations club.

#### Profile 4 Chatbot Responses to Questions:

1. Regular decision is January 1st, early action is in early November.  
Consensus: Accurate
2. Harvard's acceptance rate varies year to year and has been around 4-5%.  
Consensus: Accurate - Harvard's acceptance rate is 4%
3. Harvard provides need-based financial aid, fellowships and scholarships, a federal work-study program, and the Public Service Low-Income Protection Plan for its students.  
Consensus: Accurate - Harvard offers these options.
4. Harvard can potentially offer AP credits depending on your AP exam score.  
Consensus: Not Inaccurate, but too vague
5. The average student to teacher ratio at Harvard is about 6:1.  
Consensus: Accurate - Harvard has about a 7:1 student to teacher ratio.
6. Harvard offers numerous internships for law students that can be found using their Office of Career Services, Symplicity, On-Campus Recruiting, Public Interest Job Search, and their extensive alumni network.  
Consensus: Accurate - All of these resources are available at Harvard.
7. Harvard offers opportunities in legal research through faculty-led research projects, independent study programs, and participation in research centers with the law school. Harvard also has a debate council, Model United Nations, Harvard Club Tennis, and Harvard Classic Literature Club.



Consensus: Accurate

8. Harvard offers semester exchange programs, summer abroad programs, and independent study abroad programs. Harvard's main campus covers about 209 acres.

Consensus: Accurate

9. Law schools require the LSAT for admission and they require the GRE as an alternative.

Consensus: Accurate

#### Profile 5 Chatbot Career Plan (Consolidated):

College Recommendations:

- a) Duke University: strong social sciences program and Sanford School of Public Policy, large campus and a student-to-teacher ratio of 6:1
- b) University of North Carolina at Chapel Hill: renowned political science program and a commitment to community service, large campus and a student-to-teacher ratio of 13:1.

Major: Public Policy or Political Science with a concentration in Public Policy

Internships: Seek internships at government agencies, non-profit organizations, or policy research institutes to gain hands-on experience in public policy

Summer Programs: Institutions like Georgetown University and Harvard Kennedy School offer specialized programs in public policy and leadership.

Political Science Clubs and Organizations: Get involved in political science clubs or organizations on campus

Community Service Opportunities: Continue volunteering at local NGOs

#### Profile 5 Chatbot Responses to Questions:

1. Early decision is November 1st for early and January 1st for regular decision.  
Consensus: Inaccurate - Duke's regular decision deadline is January 3.
2. Acceptance rate 7-8%, but lower for Pratt School of Engineering.  
Consensus: Accurate - Duke's acceptance rate is 5.9% currently.
3. Offers financial aid options through merit-based scholarships, need-based financial aid, work-study programs, federal and state aid, and encouraging outside scholarships.  
Consensus: Accurate - Duke offers these options.
4. Duke awards AP exam credit for scores of 4 or 5, however some schools have limits on the amount of credits that can be applied.  
Consensus: Accurate - Duke awards credit for 4s and 5s generally.
5. The average student to teacher ratio at Duke is about 6:1.  
Consensus: Accurate - Duke's student to teacher ratio is 6:1.
6. Duke has the Sanford School of Public Policy, the Hart Leadership Program, DukeEngage, a career center, and an alumni network to find internship opportunities.  
Consensus: Accurate
7. Duke offers research opportunities for public policy through the Sanford School of Public Policy Research Centers such as the Center for Child and Family Policy, Center for the

Study of Aging and Human Development, and the Duke Center for International Development. Duke also has the Duke Political Science Union, Bass Connections, Duke Student Government, Writing Groups and Publications, and the Duke Outing Club on campus.

Consensus: Accurate - Duke has these research centers/clubs for undergraduate students.

8. Duke offers study abroad programs in Geneva, Washington D.C., and DukeEngage has immersive service programs. Duke's campus size is around 8,709 acres.

Consensus: Accurate - Duke offers these options.

9. Duke requires the GRE for the public policy graduate school and has Duke University Libraries, The Writing Studio, Tutoring and Test Prep Services for students to prepare.

Consensus: Accurate

### Profile 6 Chatbot Career Plan (Consolidated):

College Recommendations:

- a) University of California, Santa Cruz: strong environmental science program, surrounded by natural beauty and offers opportunities for outdoor exploration
- b) University of Washington: renowned Environmental Science major and is home to numerous environmental organizations and research centers, the proximity to national parks in the Pacific Northwest provides ample opportunities for environmental advocacy.
- c) University of Oregon: offers various programs related to environmental science and advocacy, close proximity to national parks, provides outdoor recreational opportunities.

Major Recommendation: Environmental Science or Environmental Studies

Job Recommendations: Environmental Advocate, Environmental Researcher, Renewable Energy Consultant

Internship Recommendations: Environmental Defense Fund, National Parks Service, Environmental Protection Agency (EPA) World Wildlife Fund (WWF)

Summer Program Recommendations: Earthwatch Institute, National Outdoor Leadership School, Environmental Summer Camps

### Profile 6 Chatbot Responses to Questions:

1. The deadline to apply to UCSC is in early January, and there are no early decision or early action options.

Consensus: Inaccurate - UCSC application deadline is November 30

2. The acceptance rate for UCSC is about 52%.

Consensus: Inaccurate - UCSC has an acceptance rate of about 58%

3. UCSC offers financial aid through scholarships, grants, work-study programs, and federal loan programs.

Consensus: Accurate

4. UCSC accepts AP scores of 3 or higher for college credit for all AP exams.

Consensus: Accurate

5. The average student to teacher ratio at UCSC is about 19:1.  
Consensus: Inaccurate - UCSC student to teacher ratio is about 25:1.
6. UCSC offers internship opportunities for environmental advocacy through Handshake, UCSC Career Center, the Environmental Studies Internship Program, and faculty/departmental support.  
Consensus: Accurate - UCSC offers all of these resources.
7. UCSC offers faculty research projects, has an Undergraduate Research Opportunities Center, and has an Environmental Studies Department that conducts research. UCSC also has the Environmental Studies Student Organization, Hiking and Outdoor Recreation Club, Photography Club, and Gardening Club.  
Consensus: Inaccurate - UCSC does not have a gardening club and photography club every year.
8. UCSC has the UC Education Abroad Program in New Zealand, Costa Rica, and other unique ecosystems for environmental science. UCSC has a campus size of 2,000 acres.  
Consensus: Accurate - UCSC is around 2,000 acres and has the UCEAP study abroad program.
9. UCSC requires the GRE for graduate school. UCSC offers their career center, libraries, academic advising, and online preparation resources for students to prepare.  
Consensus: Accurate

#### Profile 7 Chatbot Career Plan (Consolidated):

##### College Recommendation:

- a) University of Florida: offers strong sports culture, top-ranked sports management program and a variety of sports facilities, average student-to-teacher ratio of 20:1
- b) University of Georgia: renowned sports management program and a lively campus atmosphere, diverse range of sports facilities
- c) University of Alabama: strong athletics programs and offers a comprehensive sports management curriculum.

Major Recommendation: Bachelor's degree in Sports Management or a closely related field, such as Business Administration with a focus on Sports Management

Internships and Summer Programs: NCAA Internship Program, Professional Sports Teams, Sports Marketing Agencies

Jobs and Career Path: Sports Manager, Athlete Development Specialist, Sports Marketing Coordinator, and Sports Event Planner

#### Profile 7 Chatbot Responses to Questions:

1. Early action is in early November and regular decision is in early January.  
Consensus: Inaccurate - Applications are reviewed on space-available basis and must be submitted by November 1st, however, early action no longer exists at UF.
2. The Florida acceptance rate is about 34%.

Consensus: Accurate - The UF acceptance rate is about 31%.

3. University of Florida offers financial aid through scholarships, grants, work-study programs, and federal student loan programs.

Consensus: Accurate

4. University of Florida accepts scores of 3 or higher on AP Statistics, AP Psychology, and AP Government and Politics exams.

Consensus: Accurate

5. The average student to teacher ratio is 18:1 at University of Florida.

Consensus: Accurate - The student to teacher ratio is 18:1

6. Florida offers resources for internships in sports management through Gator CareerLink, Career Resource Center, Sports Management Program Advising, and Networking Events.

Consensus: Accurate

7. University of Florida offers research opportunities through the Undergraduate Research Opportunities Program and Collaborative Research programs. They also have the UF Intramural and Club Sports, the Independent Florida Alligator newspaper, UF Basketball Coaching Association, and the UF Travel Club on campus.

Consensus: Accurate - UF offers these programs and clubs on campus.

8. UF offers the Global Sport Leadership program, Sport Marketing in the Global Marketplace, and the International Sport Event Management program. The campus size is over 2,000 acres.

Consensus: Accurate

9. The GRE is required and resources can be found for preparation at the UF Academic Advising Center, UF Libraries, GRE Preparation Courses, and online resources.

Consensus: Accurate

### Profile 8 Chatbot Career Plan (Consolidated):

#### College Recommendations:

- a) Georgetown University: has a vibrant Model UN community and offers access to internships and networking opportunities in the political sphere.
- b) Columbia University: highly regarded Political Science program and offers a range of research and internship opportunities, competitive Model UN team.
- c) University of Pennsylvania: offers a dynamic campus environment and various resources for students interested in public speaking and debate.

Major Recommendation: Major in Political Science or Political Communication

Internship Recommendations: Congressional Internship, Public Speaking Internship

Summer Program Recommendations: National Student Leadership Conference on Politics and Advocacy, Debate Academy

Job Recommendations: Political Analyst, Speechwriter

### Profile 8 Chatbot Responses to Questions:

1. Regular decision is January 10th and the early action is November 1st.  
Consensus: Accurate - The deadlines are accurate.
2. The acceptance rate ranges from 14 to 16 percent at Georgetown University.  
Consensus: Inaccurate - The acceptance rate is about 12% currently.
3. Georgetown University offers need-based financial aid, scholarships, grants, work-study programs, and federal and private loan options.  
Consensus: Accurate
4. Georgetown offers college credit for scores of 4 or 5 on AP Government and Politics, AP English Language and Composition, and AP Psychology.  
Consensus: Accurate
5. The average student to teacher ratio at Georgetown University is about 11:1.  
Consensus: Accurate - The current student to teacher ratio is 11:1.
6. Offers internships through Office of Global education/Walsh School of Foreign Service.  
Consensus: Accurate - Georgetown offers these resources for its students.
7. Georgetown offers research opportunities through the Department of Government. They also have a Model UN Club, Debate Society, Philodemic Society, The Hoya newspaper, and the Georgetown Voice newspaper.  
Consensus: Accurate - Georgetown offers these opportunities and clubs on campus.
8. Georgetown offers study abroad programs including to Doha, Qatar, a semester in Washington D.C., and in London through the Center for Transnational Legal Studies. The campus size is about 104 acres.  
Consensus: Accurate - Georgetown currently offers programs to these places.
9. Georgetown graduate programs require the GRE and offer institutional support, academic advising, writing centers, and test prep courses for its students to prepare.  
Consensus - Accurate

### Profile 9 Chatbot Career Plan (Consolidated):

#### College Recommendations:

- a) University of California, Los Angeles (UCLA): strong pre-med program, research opportunities at the Ronald Reagan UCLA Medical Center, have an active pre-med club
- b) University of Washington: excellent pre-med program and access to cutting-edge research opportunities, student-to-teacher ratio of 17:1
- c) University of California, San Diego (UCSD): strong biology and healthcare programs, close ties to the nearby medical community

Major Recommendations: Biochemistry or Molecular Biology

Internship/Summer Program Recommendations: Research Internship at a Local Hospital

Career Recommendations: Pursuing medicine aligns with your biology/healthcare interests.

### Profile 9 Chatbot Responses to Questions:

1. Regular decision is November 30th and there is no early decision or early action.  
Consensus: Accurate - The regular decision deadline is November 30th.
2. The UCLA acceptance rate is about 12%.  
Consensus: Accurate - UCLA acceptance rate is about 11%
3. UCLA offers scholarships through their medical school, grants, federal loan programs, work-study programs, and research and teaching assistantships.  
Consensus: Accurate
4. UCLA awards AP credit for scores of 3 or higher on all AP exams.  
Consensus: Accurate
5. The average student to teacher ratio at UCLA is about 18:1.  
Consensus: Accurate
6. UCLA offers internships for medicine through UCLA Health, David Geffen School of Medicine, Career Center, and Handshake.  
Consensus: Accurate
7. UCLA offers medicine research opportunities through Undergraduate Research Centers, Departmental Research Programs, and Mentored Research Programs. UCLA also has Pre-Medical Student Organizations, Biology Olympiad Student Club, and a tennis team.  
Consensus: Accurate - UCLA offers these opportunities.
8. UCLA offers Travel Study Programs in East Asia, UCEAP, and GLOS for study abroad programs. The campus size is about 419 acres.  
Consensus: Accurate - UCLA has these programs available for students.
9. For medical school admission, students must pass the MCAT exam and can study using pre-health advising, workshops and information sessions, and test-prep resources.  
Consensus: Accurate

### Profile 10 Chatbot Career Plan (Consolidated):

#### College Recommendations:

- a) Georgia Institute of Technology: exceptional computer science program, state-of-the-art computer labs and a diverse range of coding and tech clubs.
- b) University of Texas at Austin: renowned computer science department, vibrant campus life, and numerous opportunities for internships and research in the technology field.
- c) North Carolina State University: strong computer science, 18:1 student-to-teacher ratio

Recommended Major: Computer Science

Summer Programs and Internships: Google CSSI, Microsoft Explore

Jobs and Roles: Software Engineer, App Developer

### Profile 10 Chatbot Responses to Questions:

1. Early action is October 15th and regular decision is January 1st.  
Consensus: Inaccurate - Early action is October 16 and regular decision is January 4th.

2. The acceptance rate at Georgia Tech is about 20%, but is lower for computer science.  
Consensus: Accurate - Georgia Tech currently has about a 18% acceptance rate
3. Georgia Tech offers scholarships, grants, work-study programs, and federal loan programs to assist students financially  
Consensus: Accurate
4. Georgia Tech grants college credit for a 4 or 5 on AP Computer Science A to earn credit for CS 1301, 4 or 5 on AP Calculus AB to earn credit for Math 1501, and 4 or 5 on AP Physics 1 to earn credit for PHYS 2211K.  
Consensus: Accurate
5. The average student to teacher ratio at Georgia Tech is about 20:1.  
Consensus: Accurate - Georgia Tech currently has a 21:1 student to teacher ratio.
6. Georgia Tech has internship opportunities that can be found through their Career Center, Co-op Programs, industry connections, and online job boards.  
Consensus: Accurate
7. Georgia Tech offers research opportunities through their College of Computing and School of Computer Science. They also have a Coding Club, GT App Lab, Game Development Club, and Association for Computing Machinery on campus.  
Consensus: Accurate
8. Georgia Tech has exchange programs, faculty-led programs, and global internships. The campus size is about 400 acres.  
Consensus: Not inaccurate, but too vague
9. Entrance exams required for computer science graduate programs are the GRE and TOEFL for international students. They offer resources through their career center, libraries, and website to help students prepare.  
Consensus: Accurate - Georgia Tech offers these resources for its students.

### **Response Accuracy Analysis**

College Application Deadlines: 40% accuracy in chatbot responses

Acceptance Rates: 60% accuracy in chatbot responses

Financial Aid Options: 100% accuracy in chatbot responses

AP Classes and College Credits: 90% accuracy in chatbot responses

College Majors and Student-to-Teacher Ratios: 80% accuracy in chatbot responses

Internship Opportunities: 100% accuracy in chatbot responses

Research Opportunities and Clubs: 90% accuracy in chatbot responses

Study Abroad Programs and Campus Size: 80% accuracy in chatbot responses

Entrance Exams for Graduate School: 100% accuracy in chatbot responses

Overall, the research findings indicate that the chatbot's strengths lie in providing reliable information on financial aid, internships, research opportunities, and entrance exams for graduate school. However, it demonstrated room for improvement in delivering accurate responses

concerning college application deadlines, acceptance rates, college majors, and student-to-teacher ratios.

The research findings revealed that the chatbot's accuracy varied across different sections of the college and career planning process. Notably, the chatbot seemed to exhibit higher accuracy in areas where information tends to remain relatively stable from year to year. For instance, it displayed impeccable accuracy when providing information about financial aid options, internship opportunities, research opportunities, and entrance exams for graduate school.

Conversely, the chatbot demonstrated room for improvement in sections where information may vary annually, such as college application deadlines, acceptance rates, college majors, and student-to-teacher ratios. As these aspects often depend on specific academic years, they require continuous updates and may be more challenging for the chatbot to maintain up-to-date accuracy.

### **Potential Bias Analysis**

1. **Historical Data Bias:** The chatbot's recommendations appear to be influenced by historical data and the prominence of certain academic programs or industries. Fields with well-established programs and clearer career trajectories, such as Computer Science and Environmental Science, receive more comprehensive recommendations. In contrast, emerging or less traditional career paths, like Music Production or Sports Management, may not receive the same level of personalized guidance.
2. **Regional Bias:** The chatbot's accuracy in identifying suitable colleges seems to be influenced by the prominence of specific institutions in certain regions. For example, West Coast-based students frequently receive recommendations for universities like Stanford and University of California campuses.
3. **Limited Representation of Emerging Fields:** The chatbot's plans may prioritize fields that have a well-established presence in the education landscape, potentially leading to the underrepresentation of emerging or less traditional career paths. This limitation could prevent students from discovering new and innovative career opportunities that align with their interests and talents.
4. **Bias in College Prestige:** The chatbot's recommendations appear to favor prestigious and well-known colleges, such as Ivy League institutions, leading to potential overlooking of other equally suitable and reputable colleges. This bias may inadvertently reinforce the notion that certain institutions are inherently superior, while others are less desirable.
5. **Limited Representation of Underrepresented Fields and Demographics:** The chatbot demonstrated varying accuracy across different sections, particularly in underrepresented career paths, diverse ethnicities, socio-economic status, college preferences, and equitable access to internship opportunities. This bias may stem from the chatbot's reliance on data sources that prioritize conventional professions and lack cultural awareness, resulting in generic advice for students from diverse backgrounds.



## Identified Risks and Limitations

1. **Limited Representation of Underrepresented Fields and Demographics:** The chatbot showed varying accuracy in offering guidance for underrepresented career paths and students from diverse ethnic backgrounds. The lack of comprehensive data on these fields and demographics within the chatbot's database could lead to generic advice and overlook valuable opportunities for students with unique aspirations and cultural values. This limitation could result in the chatbot favoring more conventional career paths and overlooking the specific needs of underrepresented groups.
2. **Age and Year-Specific Information:** The chatbot's accuracy in providing up-to-date information on college application deadlines, acceptance rates, and entrance exams may be affected by its reliance on static data sources. As such, the chatbot's recommendations might not fully account for year-to-year changes in college admissions and testing requirements, potentially leading to outdated or inaccurate information.
3. **Socio-economic Considerations:** The chatbot's ability to address the financial aspects of college, such as financial aid options and scholarships, may be limited. It might not adequately consider the diverse socio-economic statuses of the students, potentially leading to inequitable guidance and overlooking financial aid opportunities that are critical for students from low-income backgrounds.
4. **Bias in College Preferences:** The chatbot's accuracy in providing tailored college recommendations based on preferences, such as campus size and student-to-teacher ratio, showed variations. It might not adequately account for the diverse preferences of students, potentially leading to recommendations that do not fully align with the desired college experience.

## Recommendations

To address the limited representation of underrepresented fields and demographics bias, the chatbot's database should be expanded with comprehensive data that encompasses a broader range of career paths and diverse student backgrounds.

To address the limitation of age and year-specific information, the chatbot should integrate real-time data updates to ensure the accuracy of college application deadlines, acceptance rates, and entrance exam requirements. This can be achieved by accessing reliable and up-to-date data sources that continuously monitor changes in admission criteria and college-related information.

To provide more equitable advice, the chatbot should consider the socio-economic status of students when offering financial aid options and scholarship opportunities. Integrating socio-economic data into the decision-making process will ensure that the chatbot tailors recommendations to the unique financial needs of each student.

To ensure more accurate and diverse college preferences, the chatbot should broaden its criteria for recommending colleges based on campus size, student-to-teacher ratio, and other

preferences. It should consider a wider range of colleges that align with individual student preferences to avoid over-representing certain institutions.

To address potential biases and limitations, the chatbot should display disclaimers before providing recommendations, explicitly stating that the suggestions are generated by an AI-powered chatbot and may not be exhaustive or completely accurate. This will set clear expectations for users and encourage them to verify information from additional sources.

### **Improvement to Code Implementation**

I can implement a user feedback loop that allows students to provide feedback on the accuracy and usefulness of the chatbot's recommendations. This feedback can be used to refine the chatbot's performance and address any areas of concern or bias that users may identify. To ensure real-time data updates, I can integrate APIs that provide access to the latest college admission information, internship opportunities, and career trends. Regularly updating these APIs will enable the chatbot to stay current with changes in the college and job market.

### **Conclusion**

In this research study, I developed a chatbot designed to provide college and career advice based on user input, aiming to assist students in their decision-making process for their future endeavors. By entering diverse sets of demographic and statistical information for ten sample students, I tested the accuracy of the chatbot's responses across various college and career planning aspects. The results showed varying levels of accuracy for different sections, with the chatbot demonstrating higher precision in areas where information remains relatively stable year to year, such as financial aid options and internship opportunities.

During the assessment, several potential biases were detected in the chatbot's recommendations. These biases could be attributed to the underlying training data, which might not adequately represent the broad spectrum of individual experiences and opportunities. Furthermore, the chatbot's recommendations might inadvertently reflect certain societal stereotypes or preferences, possibly leading to suboptimal advice for some users.

Identified risks and limitations encompass the chatbot's reliance on static data sources, which might not account for real-time updates in college admissions or financial aid policies. Additionally, while efforts were made to incorporate diverse student profiles, the potential for inherent biases in the data could still influence the chatbot's suggestions.

To enhance the chatbot's accuracy, incorporating real-time data updates and continuously updating the training data with a more comprehensive and diverse dataset is recommended. Implementing disclaimers to highlight that the chatbot's recommendations are based on historical data and might not account for real-time changes can also help mitigate potential biases.

Improvements in the code implementation should focus on refining the model's training process, optimizing responses, and fostering adaptability to accommodate users from various backgrounds. Regular feedback and input from users can be solicited to enhance the chatbot's understanding of individual preferences and requirements.

In conclusion, this research serves as a preliminary step in utilizing AI-powered chatbots to assist students in their college and career decision-making process. While the chatbot demonstrates potential in offering helpful advice, it is essential to remain vigilant about potential biases and continuously improve the model to ensure accurate, fair, and personalized recommendations. Through ongoing development and user feedback, AI-driven college and career advisors can evolve into valuable tools, empowering students with personalized guidance and support as they navigate their future paths.

## Work Cited

- Stanford University. "Stanford University." Accessed July 25, 2023.  
[www.stanford.edu/](http://www.stanford.edu/).
- "Berklee College of Music." Berklee.edu. Accessed July 25, 2023.  
[www.berklee.edu/](http://www.berklee.edu/).
- "UCLA." Ucla.edu. Accessed July 25, 2023.  
[www.ucla.edu/](http://www.ucla.edu/).
- "University of California, Santa Cruz." Ucsd.edu. Accessed July 25, 2023.  
[www.ucsc.edu/](http://www.ucsc.edu/).
- "Duke University." Duke.edu. Accessed July 25, 2023.  
[www.duke.edu/](http://www.duke.edu/).
- Georgia Institute of Technology. "Georgia Tech." Gatech.edu. Accessed July 25, 2023.  
[www.gatech.edu/](http://www.gatech.edu/).
- University of Florida. "University of Florida." Ufl.edu. Accessed July 25, 2023.  
[www.ufl.edu/](http://www.ufl.edu/).
- Harvard University. "Harvard." Harvard University. Accessed July 26, 2023.  
[www.harvard.edu/](http://www.harvard.edu/).
- "Georgetown." Georgetown.edu. Accessed July 26, 2023.  
[www.georgetown.edu/](http://www.georgetown.edu/).
- "School of the Art Institute of Chicago |." Saic.edu. Accessed July 27, 2023.  
[www.saic.edu/](http://www.saic.edu/).
- "US News Education | Best Colleges | Best Graduate Schools | Online Schools." @USNews.  
Accessed July 25-27, 2023.  
[www.usnews.com/education](http://www.usnews.com/education).
- College Board. "The College Board - College Admissions - SAT - University & College Search Tool." Collegeboard.org. Accessed July 25-27, 2023.  
[www.collegeboard.org/](http://www.collegeboard.org/).
- "Get into Your Dream University." Crimson Education. Accessed July 25-27, 2023.  
[www.crimsoneducation.org/](http://www.crimsoneducation.org/).
- Niche. "Niche: Explore Schools, Companies, and Neighborhoods." Niche. Accessed July 25-27, 2023.  
[www.niche.com/](http://www.niche.com/).
- Staff Writers. "2019 College Rankings - Find the School for You! | BestColleges.com." BestColleges.com, BestColleges.com. Accessed July 25-27, 2023.  
[www.bestcolleges.com/](http://www.bestcolleges.com/).
- "University HQ: Helping You Find the Best Ranked Online Colleges, Degrees & Scholarships." Universityhq.org. Accessed July 25-27, 2023.  
[universityhq.org/](http://universityhq.org/).

## **Addressing Diversity, Bias, and Health Disparities Curricula in Medical Education By Pristine Cyril, Nilay Kolli, and Joseph Nidhiry**

### **Abstract**

Increasing diversity, repelling bias, and presenting health disparities curricula in medical education are crucial in developing the capabilities of medical students to address health disparities as future healthcare professionals. This paper aims to highlight the current shortcomings and implications of diversity, bias, and curricula standards in medical education. Diversity within medical education is fundamental for creating a diverse workforce, improving patient satisfaction and health outcomes, combating unconscious bias, and mitigating health disparities. Underrepresentation in the medical community has detrimental impacts on physician-distribution geographically and physician-preparedness to work with diverse populations which disproportionately impacts health outcomes of marginalized groups. Though there has been some improvement in medical school matriculant diversity, there is extensive work that needs to be done especially in the context of recent Supreme Court rulings ending race-based affirmative-action policies. Recommendations include encouraging diversity in leadership positions within medical schools, promoting medical professions at each level of education to underrepresented groups, promoting programs and policies that foster diversity in healthcare, and improving accessibility to opportunities and resources that aid that experience. Bias in medical education and admissions also acts as another barrier for minority students, negatively impacting social integration, educational experiences, performance, future career opportunities, and overall minority success in medicine. Combating such bias requires effective bias training, appropriate reporting and disciplinary systems, and novel tools like the Implicit Association Test (IAT). Finally, the lack of medical schools integrating quality health disparities curricula is problematic as health disparities have real implications on health access and outcomes of marginalized groups. Implementing and improving health disparities curricula in medical schools is a necessary step to properly prepare future physicians with the tools necessary to address and combat these inequities.

### **Introduction**

The idea of race as a social construct was historically used to divide the human population that ultimately created power imbalances between White populations and people of color over time. In the United States, these power imbalances manifested themselves in oppressive structures like slavery and the socioeconomic and political marginalization of people of color. Systemic oppression has led to inequalities when it comes to accessing opportunities, resources, and equal protection (Pérez-Stable and Hooper). Such inequalities have penetrated multiple facets of healthcare, including medical education. Historically, racism and segregation in medical school admissions, educational experiences, and career opportunities have created barriers for minority students training to become physicians, creating a lack of diversity in the medical field (Daher et al.). Prior to 1865, Black students had no access to medical schools in the

South and limited access to medical schools in the North. After 1865, some medical schools for Black students were formed (*LibGuides: Black History Month: A Medical Perspective: Education*). However, many of these schools were closed after the 1910 Flexner Report which reflected the belief that training Black doctors was unnecessary, thereby excluding many Black students from advancing in the field (Flexner). Oftentimes, admission to medical schools required applicants to meet certain educational criteria that often catered to White populations since Black students often faced far more socioeconomic and political barriers that prevented success in such educational pursuits (Baker et al.). Despite efforts to combat these disparities over the last few decades such as “pipeline programs” and legislative efforts like Title VII to increase the diversity of healthcare workers, there still remain notable discrepancies (Puscas).

The Centers for Disease Control and Prevention (CDC) defines “health disparities” as “preventable differences in the burden of disease, injury, violence, or opportunities to achieve optimal health that are experienced by socially disadvantaged populations”. Health disparities can have a large impact on the treatment or outcome of a patient and can manifest in situations where treatment is unaffordable or inaccessible (Centers for Disease Control and Prevention). Increasing diversity, repelling bias, and presenting health disparities curricula in medical education are all crucial in developing the capabilities of prospective physicians when it comes to addressing such disparities and treating diverse groups.

## **Methods**

A literature review on health disparities and medical education was conducted using the databases PubMed Central, Taylor & Francis Online, and MedEdPORTAL, works cited from other relevant literature, and Google searches to narrow our topic of interest. When deciding on the sources to use, we valued literature that was recent and relevant to our research. Information and data gathered by organizations and institutions like the Centers for Disease Control and Prevention (CDC), the Association of Medical Colleges (AAMC), and the American Medical Association (AMA) were also included in this review. The scope of this paper is focused on the United States.

## **Diversity in Medical Education**

Diversity within medical education is pivotal for creating a diverse workforce that improves patient-care and health outcomes, fights unconscious bias, and mitigates health disparities.

There is a lack of diversity in multiple disciplines of medicine, and the American Association of Medical Colleges (AAMC) reports that over half of practicing physicians are found to be White (“Figure 18. Percentage of All Active Physicians by Race/Ethnicity, 2018 | AAMC”). Previous literature indicates that first-year medical school matriculants were only 8% Black and 6.9% Hispanic or Latino in 2021. Hispanic and Black dermatology applicants made up only 4.8% and 7.8% of the applicant pool respectively in the 2020-2022 cycle (Hooper et al.). Plastic surgery is another field which African Americans and Hispanics are similarly

underrepresented in, and there exists a bottleneck effect in Hispanic and African American residents as applicants exceed those actually in residency (Silvestre et al.).

This underrepresentation has real implications. Physicians that come from racial minorities are much more likely to work in underrepresented communities. However, studies indicate that there is a lack of physicians in counties where people of color make the majority. A lack of diversity in healthcare not only limits physician-distribution and access to quality healthcare, but also physician-preparedness to work with diverse groups and fight unconscious bias, disproportionately impacting the health outcomes of marginalized groups (Cskopecce). Unconscious biases are defined as preconceived notions, prejudices, or stereotypes about a particular group that one may not be actively aware of (*Unconscious Bias Training | Office of Diversity and Outreach UCSF*). In the United States, such minorities are shown to have lower life expectancies, increased rates of deaths, and higher rates of illnesses like diabetes, hypertension, obesity, asthma, and heart disease than white populations. These health disparities were also exacerbated by the COVID-19 pandemic as racial and ethnic minorities faced a disproportionate impact (“Racism and Health”). Moreover, White women are 2-3 times less likely to face a pregnancy-related death than their Native American and Black counterparts (“CDC Newsroom”).

Fortunately, diversity in medicine has a plethora of benefits. For example, surgical training programs supportive of diversity have been found to attract women and minorities and tend to be more highly ranked (Ku et al.). A wider range of perspectives is also beneficial to the learning environment and advancing medicine as a whole. A study analyzing the relationship between diversity in groups of first year medical students and their team-based learning outcomes suggests a positive correlation between the two (Ganguly et al.). Exposure to working with and socializing among diverse groups of students is shown to increase self-rated preparedness when it comes to working with and caring for people of various backgrounds (Niu et al.). Furthermore, studies show longer visit times and higher reported levels of trust and satisfaction among patients of the same race or ethnicity as the physician (Rothman). Further research indicates diversity in healthcare is associated with better clinical decision making which has direct implications on health outcomes and patient satisfaction (“Disparities in Patient Experiences, Health Care Processes, and Outcomes: The Role of Patient-Provider Racial, Ethnic, and Language Concordance”).

Recent efforts to improve diversity in medical schools have been slowly seeing results. The AAMC reports there was a 9% increase in Black medical school matriculants and 4% increase for Hispanic or Latino matriculants in the 2022-2023 cycle. However, Native American and Alaska Native matriculants appeared to have decreased by 9%. Data also indicates a slightly increased diversity of socioeconomic status (“Diversity Increases at Medical Schools in 2022”). However, with the recent 2023 Supreme Court ruling in *Students for Fair Admissions, Inc. v. President and Fellows of Harvard College* ending affirmative action and race-based college admissions, it is unclear whether this progress will be undermined (American Medical Association and American Medical Association). Colleges and universities will likely have to

find other ways to overcome the ruling and foster diversity efforts. It is very possible that the ruling will act as an obstacle for underrepresented groups in the admissions process, and this may ultimately impact medical school demographics for the worse as well. Recommendations to continue lessening the divide include encouraging diversity in leadership positions within medical schools, promoting medical professions at each level of education, supporting programs and policies that work towards fostering interest in healthcare professions in underrepresented communities, and providing access to various opportunities to aid that experience. It is also important to address the systemic and financial barriers that make medical school more inaccessible to marginalized communities.

Diversity ultimately plays a significant role in the quality of medical school education, physician-preparedness, physician-distribution, patient-care, patient satisfaction and trust, clinical decision-making, and overall health outcomes.

### **Bias in Medical Education**

Bias in medical education is also shown to affect medical students in various aspects of their daily lives. Whether it be based on race, gender, or any other aspect of identity, the effects of bias and stereotyping are evidenced to hold a certain influence over medical students' attitudes, self-image, success, and overall experiences in medical education.

In a series of qualitative interviews at a British Medical School, Black medical students expressed feeling the need to constantly "justify" their own intelligence, conforming to certain conventions associated with a healthcare setting and denying self-expression, all in order to avoid judgment due to racial stereotyping. In the same study, no White or Asian students reported feeling such social pressures. Additionally, some minority students expressed concern about their future career potential due to barriers formed by their ethnicities. This, in turn, negatively affected students' mental health by generating an atmosphere where additional racial stress added to the usual stress of medical school (Lempp and Seale).

In a second study, 184 medical students (52% of which were female, and 26% of which were part of an ethnic minority) were administered the Stereotype Vulnerability Scale (SVS) test, a quantitative assessment of a perceived stereotype threat. In total, 28% of all participating students showed a high stereotype threat vulnerability, with 82% of Black students, 45% of Asian students, 43% of Latinx students, and only 4% of White students reflecting SVS scores indicating so. This indicates a disproportionate rate of SVS among minority students. In a following series of qualitative interviews among eighteen students who scored a high SVS, many minority students expressed feeling more self-conscious after they noticed being in a group in which there were little to no others who shared their ethnicity. These students reported feeling pressured to act a certain way in order to avoid stereotyping and judgment (Bullock et al.).

Additionally, in an interview of 64 medical and biomedical students as well as 8 staff members, many Black students expressed feeling like they had to work much harder than the ethnic majority in order to obtain the same level of respect. Many other students also reported seeing a lack of social integration due to ethnic and racial boundaries in their student body. In



addition, many Black and Middle Eastern students indicated being culturally stereotyped by faculty members and other students. In the same study, staff members also observed that many minority students seemed to have fewer networking opportunities in comparison to their ethnic majority counterparts, as well as a lack of social integration in both lectures and extracurricular settings (Claridge et al.).

In a separate study conducted at the Ohio State University College of Medicine (OSUCOM), the Black-White Implicit Association Test (IAT) was administered to 140 total medical school staff members and students in order to measure the prevalence of White-favoring implicit racial bias. This study's sample as a whole, which included 43 faculty members and 97 medical students, exhibited a substantial degree of implicit White preference, with faculty members having greater bias measures than students (Capers et al.).

Bias in medical institutions has real implications on overall minority success in medicine. In a sample of 33,389 allopathic medical school students in the United States, Yale Medical School researchers found that compared to non-hispanic White medical students (2.3%), Hispanic (5.2%), Native American (11.0%), and African American medical students (5.7%) were significantly more likely to drop out sometime during medical school (Nguyen et al.). This can be partially attributed to added social pressures, stress, and discrimination that underrepresented communities face within medical institutions.

Widespread implementation of in-depth bias training for students and faculty has the potential to counteract the effects of bias. By educating students and faculty on how to both identify and address bias and discrimination, training programs can be an effective tool for eliminating prejudices in medical institutions. Improving reporting systems and disciplinary actions for incidents of bias and discrimination within schools may also be valuable for combating bias. Not only may it serve to appropriately handle situations that have already occurred, but it may also be beneficial in deterring future incidents.

The IAT, which evaluates the strength of stereotypes and implicit associations between ideas, may also be valuable when identifying and combating bias in the field. Just prior to the 2012-2013 admissions cycle, the aforementioned study conducted at the Ohio State University College of Medicine (OSUCOM) had the admissions committee take a Black-White IAT. Notable levels of implicit White preference were measured across several groups, including men, women, students, and faculty. When reviewing applicants for that following cycle, 48% of surveyed faculty on the admissions committee reported being aware of their IAT results, and 21% confirmed that their decisions were influenced by knowledge of their IAT results. As a result, OSUCOM achieved their most diverse matriculating class in the 2012-2013 cycle (Capers et al.). Furthermore, a study spanning 49 U.S. medical schools found that students who took the Black-White IAT during medical school were statistically more likely to have a decrease in implicit racial bias (Van Ryn et al.). Taking the IAT likely contributes to decreasing bias because it allows participants to become conscious of otherwise unknown, implicit associations that may be impacting their perspectives and actions.

Overall, the various challenges posed to minority medical students due to bias may suppress aspiring physicians from realizing their fullest capabilities in the field of medicine. Bias can affect minority students' well-being, performance, educational experience, and career opportunities. Implementing effective bias training widespread, improving incident-reporting measures, and utilizing tools like the IAT may be a crucial first step in overcoming this issue.

### **Health Disparities Curricula in Medical Education**

In order to fight against the prevalence of health disparities in medicine, it is necessary for healthcare professionals to possess knowledge of them and have the capacity to combat their propagation in a medical setting. This course of action is hindered by the lack of universities teaching health disparities curricula. According to the AAMC, only 40% of medical schools reported instructing health disparities curricula in 2018 (Weiner). Furthermore, low-quality curricula may negate the benefits of health disparities education. In a 2017 survey of family medicine department chairs regarding their experience with health disparities curricula, although 92% of respondents reported that their medical school curricula included instruction on racial and ethnic disparities, 65% believed more curricular content was necessary, and 56% did not deem the quality of their course ideal (Chen et al.). The quality of such educational materials is very important as low-quality curricula would only fail to provide future healthcare professionals with an adequate understanding of health disparities and the tools necessary to combat them.

The need for more, high-quality health disparities education programs is also demonstrated by the current state of health inequities. Ensuring medical students are thoroughly cognizant of these inequities is crucial to learning how to deliver better patient-care and determining the best methods to address such disparities. One example of the current state of health disparities is the discrepancy between Indigenous and White populations. In comparison to White people, Native Americans and Alaska Natives have a 60% higher infant mortality rate (National Academies Press (US)). Mental health disparities are also present; Native Americans are more likely to experience PTSD and psychological distress than the general United States population (Zein). Furthermore, Alaska Natives had a 73% higher overall suicide rate between 2002-2004 than the national average in 2003 (Herne et al.). Another example of the current state of disparities in the United States is in regards to gender. One study finds that men ages 12 and older report higher rates of alcohol and illicit drug usage than women in the same age group while women are more likely to have a severe mental illness (SAMHSA). The current state of disparities is also illustrated in LGBT communities. LGBT populations are more likely to experience bullying, commit suicide, contract sexually transmitted diseases, and engage in substance abuse than the general population (Robinson and Espelage). These discrepancies demonstrate the significance of health disparities in the United States. Adequately educating medical students about such disparities is vital to combating them and preparing students in the field overall.

Incorporating quality health disparities education has been shown to be effective in improving patient-care and minority health outcomes, dismantling bias, and combating health

inequities itself. According to one study that created a health disparities course taught to residents in the Tinsley Harrison Internal Medicine Residency Program at the University of Alabama at Birmingham, 63% of the subjects improved in 15 of the 20 measured domains which encompassed themes such as improving doctor-patient communication, utilizing community resources, soliciting patient perceptions, and identification of bias (*Family Medicine*). Another study implementing a health disparities course at the Ohio State University's Department of Family and Community Medicine Residency program found that residents who took part in the course had an increased efficacy in caring for uninsured, LGBTQ+, and immigrant populations compared to pre-course efficacy levels. These residents also had increased efficacy in caring for Medicaid-insured patients compared to residents following the general resident curriculum (Johnson et al.). A further investigation implementing a health disparities course for neurology residents at the Hospital of the University of Pennsylvania found that a majority of participants responding in a post-course survey reported that “the curriculum was at least somewhat effective in addressing health disparities (90%), cultural competency (81%), and implicit bias (81%)” (Mendizabal et al.).” Implementing health disparities curricula can attract students from minorities that are underrepresented in the medical field and promote a sense of inclusion at medical schools. This promotes diversity in the medical field, which, as mentioned previously, can create a physician workforce that is better equipped to serve underrepresented communities [11, 38]. Additionally, education about minority health for medical students improves patient outcomes (Treacy-Abarca et al.). With time and the right momentum, these studies all demonstrate the value and feasibility of implementing health disparities curricula in medical schools by highlighting their effectiveness in capacitating future healthcare professionals to close the gap.

### **Limitations**

These recommendations come with several limitations, however. One limitation includes controversy about the best programs and policies to implement in order to promote a diverse student body. Finding support for such initiatives in non-diverse areas is a challenge in itself. The recent Supreme Court ruling in *Students for Fair Admissions, Inc. v. President and Fellows of Harvard College* may have real implications on diversity efforts in medical schools as underrepresented populations, who often face many added socioeconomic and environmental barriers, will likely have a harder time being accepted into undergraduate schools. This will likely trickle down to a less diverse medical school applicant pool. Additionally, other limitations include debate on what actually determines a quality curriculum. Differences in definitions and ideologies make standardizing curricula and bias training more difficult. Another important limitation is our ability to actually quantify the degree to which diversity, bias, and educational materials in medical institutions impact health disparities itself. Though there are several links between them, there are many other factors and social determinants that impact these health inequities. Our society's current symptomatic approach has been unsuccessful. Ultimately, many of these issues are institutionally rooted due to a history of oppression and injustices against

many marginalized communities over the centuries. In order to make permanent and significant change, grassroots advocacy and multidisciplinary initiatives are required. In regards to the scope of this paper itself, much of this research is limited to the United States. The United States, having a unique history, presents unique discrepancies in its systems. Further research on health access and outcomes in other nations may be a necessary step to addressing these issues as a whole.

## **Conclusion**

This review paper emphasizes the significance of diversity, bias, and health disparities curricula within medical education and provides recommendations to improve them.

It is evident that there is a current insufficiency of diversity within the healthcare field, with there being a pronounced underrepresentation of ethnic minorities such as Blacks and Hispanics [8-10]. This lack of diversity, which manifests itself widely in the form of similar skewed demographic data, is evidenced to negatively impact both the efficiency and efficacy of the existing healthcare system [11, 13-14]. Consequently, increased diversity within the educational setting is shown to improve team-based learning outcomes, self-rated preparedness, trust and satisfaction levels among patients, and overall clinical decision making [15-19]. Despite recent improvements in medical school demographics, the Supreme Court ruling on ending race-based college admissions may have detrimental impacts on diversity efforts in medical schools [20-21]. Recommendations to counter this include encouraging diversity in leadership positions within medical schools, promoting medical professions at each level of education, and supporting programs and policies that work towards fostering interest and opportunity in medicine for underrepresented communities.

Additionally, widespread bias in the educational setting is definitively shown to negatively impact many medical students in their daily lives. It is clear that not only are minority groups proven to be more susceptible to stereotype threat, but many minority students, for fear of evident and ongoing social discrimination, report feeling socially pressured to justify their intelligence, act contrary to common stereotypes, and deny self-expression in order to avoid negative judgment from faculty and peers due to racial bias. This discrimination is shown to carry significant consequences for minority students, negatively impacting mental health, social integration, performance, networking options, and overall success in medicine. Such obstacles may prevent these students from reaching their fullest potential as practicing physicians [22-26]. Implementing effective bias-trainings for students and staff in medical schools, improving reporting and disciplinary systems, and utilizing tools like the Implicit Association Test (IAT) are important steps to address this [27].

Finally, only a limited percentage of medical schools are shown to implement health disparities education into their curricula, and often the quality of these curricula is reportedly sub-par [28-29]. As a result, many students are not adequately educated about widespread health disparities prevalent in society today. The current state of health disparities reflects a need for change [30-34]. Since high-quality health disparities curricula have been shown to be both

effective and feasible to implement, integrating and improving said curricula may provide students the knowledge necessary to combat health disparities in practice [35-38].

Ultimately, improving diversity, bias, and disparities curricula in medical schools are vital to improving physician-preparedness, patient-care, health outcomes and disparities, minority success, and medicine as a whole.

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## Works Cited

- American Medical Association and American Medical Association. "If Affirmative Action's Struck Down, What's Next for Medical Schools?" *American Medical Association*, 14 Apr. 2023, [www.ama-assn.org/education/medical-school-diversity/if-affirmative-action-s-struck-down-what-s-next-medical-schools](http://www.ama-assn.org/education/medical-school-diversity/if-affirmative-action-s-struck-down-what-s-next-medical-schools).
- Baker, Robert, et al. "Creating a Segregated Medical Profession: African American Physicians and Organized Medicine, 1846-1910." *Journal of the National Medical Association*, vol. 101, no. 6, Elsevier BV, June 2009, pp. 501–12. [https://doi.org/10.1016/s0027-9684\(15\)30935-4](https://doi.org/10.1016/s0027-9684(15)30935-4).
- Bullock, Justin L., et al. "They Don't See a Lot of People My Color: A Mixed Methods Study of Racial/Ethnic Stereotype Threat Among Medical Students on Core Clerkships." *Academic Medicine*, vol. 95, no. 11S, Lippincott Williams and Wilkins, Oct. 2020, pp. S58–66. <https://doi.org/10.1097/acm.0000000000003628>.
- Capers, Quinn, et al. "Implicit Racial Bias in Medical School Admissions." *Academic Medicine*, vol. 92, no. 3, Lippincott Williams and Wilkins, Mar. 2017, pp. 365–69. <https://doi.org/10.1097/acm.0000000000001388>.
- "CDC Newsroom." *CDC*, 1 Jan. 2016, [www.cdc.gov/media/releases/2019/p0905-racial-ethnic-disparities-pregnancy-deaths.htm](http://www.cdc.gov/media/releases/2019/p0905-racial-ethnic-disparities-pregnancy-deaths.htm)  
Centers for Disease Control and Prevention. "Health Disparities." *CDC*, 26 May 2023, [www.cdc.gov/healthyyouth/disparities/index.html](http://www.cdc.gov/healthyyouth/disparities/index.html).
- Chen, Frederick M., et al. "Racial and Ethnic Health Disparities Curricula in US Medical Schools: A CERA Study." *PRiMER: Peer-review Reports in Medical Education Research*, vol. 1, June 2017, <https://doi.org/10.22454/primer.2017.1.6>.
- Claridge, Hugh, et al. "The Ethnicity Attainment Gap Among Medical and Biomedical Science Students: A Qualitative Study." *BMC Medical Education*, vol. 18, no. 1, BioMed Central, Dec. 2018, <https://doi.org/10.1186/s12909-018-1426-5>.
- Cskopecce. "The Importance and Benefits of Diversity in Health Care | SGU." *Medical Blog*, 16 May 2023, [www.sgu.edu/blog/medical/pros-discuss-the-importance-of-diversity-in-health-care](http://www.sgu.edu/blog/medical/pros-discuss-the-importance-of-diversity-in-health-care).
- Daher, Yasmeen, et al. "The History of Medical Education: A Commentary on Race." *Journal of Osteopathic Medicine*, vol. 121, no. 2, De Gruyter, Jan. 2021, pp. 163–70. <https://doi.org/10.1515/jom-2020-0212>.
- "Disparities in Patient Experiences, Health Care Processes, and Outcomes: The Role of Patient-Provider Racial, Ethnic, and Language Concordance." *Commonwealth Fund*, 1 July 2004, [www.commonwealthfund.org/publications/fund-reports/2004/jul/disparities-patient-experiences-health-care-processes-and](http://www.commonwealthfund.org/publications/fund-reports/2004/jul/disparities-patient-experiences-health-care-processes-and).
- "Diversity Increases at Medical Schools in 2022." *AAMC*, 13 Dec. 2022, [www.aamc.org/news-insights/press-releases/diversity-increases-medical-schools-2022#:~](http://www.aamc.org/news-insights/press-releases/diversity-increases-medical-schools-2022#:~)

:text=Diversity%20of%20enrollees&text=Black%20or%20African%20American%20students.

*Family Medicine*. [www.stfm.org/FamilyMedicine/Vol49Issue10/Noriea796](http://www.stfm.org/FamilyMedicine/Vol49Issue10/Noriea796).

“Figure 18. Percentage of All Active Physicians by Race/Ethnicity, 2018 | AAMC.” *AAMC*, [www.aamc.org/data-reports/workforce/data/figure-18-percentage-all-active-physicians-race/ethnicity-2018](http://www.aamc.org/data-reports/workforce/data/figure-18-percentage-all-active-physicians-race/ethnicity-2018).

Flexner, Abraham. “Medical Education in the United States and Canada.” *Science*, vol. 32, no. 810, American Association for the Advancement of Science, July 1910, pp. 41–50. <https://doi.org/10.1126/science.32.810.41>.

Ganguly, Anisha, et al. “Association of Group Composition Diversity and Performance Outcomes in a Pre-clerkship Team-based Learning Program.” *Medical Teacher*, vol. 41, no. 9, Informa, May 2019, pp. 1060–64. <https://doi.org/10.1080/0142159x.2019.1616682>.

Herne, Mose, et al. “Suicide Mortality Among American Indians and Alaska Natives, 1999–2009.” *American Journal of Public Health*, vol. 104, no. S3, American Public Health Association, June 2014, pp. S336–42. <https://doi.org/10.2105/ajph.2014.301929>.

Hooper, Jette, et al. “Racial/Ethnic Health Disparities in Dermatology in the United States, Part 1: Overview of Contributing Factors and Management Strategies.” *Journal of the American Academy of Dermatology*, vol. 87, no. 4, Elsevier BV, Oct. 2022, pp. 723–30. <https://doi.org/10.1016/j.jaad.2021.12.061>.

Johnson, Christen, et al. “Pathways to Equity: A Pilot Study Implementing a Health Equity Leadership Curriculum in Residency Education as an Antidote to Systemic Racism.” *Journal of the National Medical Association*, Elsevier BV, Jan. 2022, <https://doi.org/10.1016/j.jnma.2021.12.015>.

Ku, Manwai C., et al. “Decisions, Decisions: How Program Diversity Influences Residency Program Choice.” *Journal of the American College of Surgeons*, vol. 213, no. 2, Elsevier BV, Aug. 2011, pp. 294–305. <https://doi.org/10.1016/j.jamcollsurg.2011.04.026>.

Lempp, Heidi, and Clive Seale. “Medical Students’ Perceptions in Relation to Ethnicity and Gender: A Qualitative Study.” *BMC Medical Education*, vol. 6, no. 1, BioMed Central, Mar. 2006, <https://doi.org/10.1186/1472-6920-6-17>.

*LibGuides: Black History Month: A Medical Perspective: Education*. [guides.mclibrary.duke.edu/blackhistorymonth/education](http://guides.mclibrary.duke.edu/blackhistorymonth/education).

Mendizabal, Adys, et al. “Feasibility and Effectiveness Appraisal of a Neurology Residency Health Equities Curriculum.” *Journal of the Neurological Sciences*, vol. 431, Elsevier BV, Dec. 2021, p. 120040. <https://doi.org/10.1016/j.jns.2021.120040>.

National Academies Press (US). “The State of Health Disparities in the United States.” *Communities in Action - NCBI Bookshelf*, 11 Jan. 2017, [www.ncbi.nlm.nih.gov/books/NBK425844](http://www.ncbi.nlm.nih.gov/books/NBK425844).

Nguyen, Mytien, et al. “Association of Sociodemographic Characteristics With US Medical Student Attrition.” *JAMA Internal Medicine*, vol. 182, no. 9, American Medical Association, Sept. 2022, p. 917. <https://doi.org/10.1001/jamainternmed.2022.2194>.

- Niu, Nina N., et al. "The Impact of Cross-Cultural Interactions on Medical Students' Preparedness to Care for Diverse Patients." *Academic Medicine*, vol. 87, no. 11, Lippincott Williams and Wilkins, Nov. 2012, pp. 1530–34. <https://doi.org/10.1097/acm.0b013e31826d40f5>.
- Pérez-Stable, Eliseo J., and Monica Webb Hooper. "Acknowledgment of the Legacy of Racism and Discrimination." *Ethnicity & Disease*, vol. 31, no. Suppl, Ethnicity and Disease, Inc., May 2021, pp. 289–92. <https://doi.org/10.18865/ed.31.s1.289>.
- Puscas, Liana. "Promising Practices Among Pathway Programs to Increase Diversity in Medicine." *Council on Medical Education*, no. 5, June 2021.
- "Racism and Health." *Centers for Disease Control and Prevention*, 18 Sept. 2023, [www.cdc.gov/minorityhealth/racism-disparities/index.html](http://www.cdc.gov/minorityhealth/racism-disparities/index.html).
- Robinson, Joseph P., and Dorothy L. Espelage. "Peer Victimization and Sexual Risk Differences Between Lesbian, Gay, Bisexual, Transgender, or Questioning and Nontransgender Heterosexual Youths in Grades 7–12." *American Journal of Public Health*, vol. 103, no. 10, American Public Health Association, Oct. 2013, pp. 1810–19. <https://doi.org/10.2105/ajph.2013.301387>.
- Rothman, Paul B., MD. "Diversity in Medicine Has Measurable Benefits." *Johns Hopkins Medicine*, 27 May 2016, [www.hopkinsmedicine.org/news/articles/diversity-in-medicine-has-measurable-benefits](http://www.hopkinsmedicine.org/news/articles/diversity-in-medicine-has-measurable-benefits).
- Silvestre, Jason, et al. "Racial and Ethnic Diversity of U.S. Plastic Surgery Trainees." *Journal of Surgical Education*, vol. 74, no. 1, Elsevier BV, Jan. 2017, pp. 117–23. <https://doi.org/10.1016/j.jsurg.2016.07.014>.
- Substance Abuse and Mental Health Services Administration Center for Behavioral Health Statistics and Quality. "RESULTS FROM THE 2014 NATIONAL SURVEY ON DRUG USE AND HEALTH: DETAILED TABLES." *SAMHSA*, 2014.
- Treacy-Abarca, Sean, et al. "Enhancing Existing Medical School Curricula With an Innovative Healthcare Disparities Curriculum." *BMC Medical Education*, vol. 21, no. 1, BioMed Central, Dec. 2021, <https://doi.org/10.1186/s12909-021-03034-7>.
- Unconscious Bias Training | Office of Diversity and Outreach UCSF*. [diversity.ucsf.edu/programs-resources/training/unconscious-bias-training](http://diversity.ucsf.edu/programs-resources/training/unconscious-bias-training).
- Van Ryn, Mph Michelle, et al. "Medical School Experiences Associated With Change in Implicit Racial Bias Among 3547 Students: A Medical Student CHANGES Study Report." *Journal of General Internal Medicine*, vol. 30, no. 12, Springer Science+Business Media, July 2015, pp. 1748–56. <https://doi.org/10.1007/s11606-015-3447-7>.
- Weiner, Stacy. "Medical Schools Overhaul Curricula to Fight Inequities." *AAMC*, 29 June 2022, [www.aamc.org/news-insights/medical-schools-overhaul-curricula-fight-inequities](http://www.aamc.org/news-insights/medical-schools-overhaul-curricula-fight-inequities).
- Zein, Mira. "Mental Health Disparities: American Indians and Alaska Natives." *American Psychiatric Association*, 2017.



# **The Effect of Artificial Intelligence on Motivation and Productivity Among High School Students By Sarthak Gupta and Jasmine Lane**

## **Abstract**

The rapid integration of Artificial Intelligence (AI) into educational settings raises critical questions regarding its influence on student motivation and productivity. This study investigates the complex relationship between AI usage frequency and the perception of AI-induced laziness and lack of self-motivation among high school students in Hillsborough County, Florida, USA. Utilizing a quantitative research approach, a structured survey was administered to 254 participants, capturing data on AI interaction patterns and perceptions. The findings reveal compelling insights into the relation between AI and lack of self-motivation amongst high school students. Notably, a statistically significant association (chi-square test of independence,  $p < 0.05$ ) emerged between AI usage frequency and the perception of AI's impact on laziness. Students who reported regular or frequent AI usage were more likely to perceive AI as making them lazier, while occasional and rare users exhibited a lower likelihood of such perception. These results highlight the need for a nuanced understanding of AI's role in education. While AI offers myriad benefits, including personalized learning experiences, our study highlights the importance of considering its potential consequences on student motivation. Educators, policymakers, and technology developers must collaborate to harness AI's advantages while mitigating its perceived drawbacks. This research contributes to the evolving discourse on AI in education and underscores the significance of balanced AI integration that fosters student engagement and self-motivation.

Keywords: Artificial Intelligence, Education, High School Students, Motivation, Productivity, Perception, Technology Integration, Hillsborough County.

## **Introduction**

In an era defined by the relentless march of technological progress, the incorporation of Artificial Intelligence (AI) into our daily lives has become not just commonplace, but often indistinguishable from the norm. From virtual assistants like Siri and Alexa, which utilize voice recognition technology to perform tasks such as setting reminders, providing weather updates, and controlling smart home devices, to chatbots like ChatGPT and Google Bard, which engage in natural language conversations, answer a wide range of questions, and offer recommendations on various topics, AI has infiltrated our world, seamlessly integrating into our daily routines and enhancing our access to information and assistance. While this technological evolution brings with it numerous advantages, it also raises a pressing concern: how does the omnipresence of AI influence the motivation and productivity of people, a demographic at the crucial nexus of education and technology?

At the core of this concern is the question of how AI impacts human motivation and behavior. As AI-driven technologies become increasingly pervasive, they offer unprecedented

convenience, information access, and entertainment options. Yet, as the allure of AI's instant gratification beckons, a shadow looms – the specter of laziness. This research delves into this intricate relationship between AI and motivation, seeking to elucidate whether AI serves as a catalyst for laziness or a tool for empowerment.

The importance of this inquiry cannot be undermined. As society progresses towards an AI-augmented future, understanding its effects on individuals is not merely an academic exercise; it is essential for educators, parents, as well as policymakers. Are we nurturing a generation dependent on AI to the detriment of their intrinsic motivation or are we fostering adaptable learners who harness AI as a collaborator to amplify their potential? The answers to these questions hold implications for the future of education, workforce readiness, and our collective capacity to exploit the benefits of AI responsibly.

This research paper embarks on a comprehensive exploration, combining a review of existing literature with original data collection and analysis to shed light on the intricate relationship between AI and the phenomenon of laziness among high school students. By examining the motivations, attitudes, and behaviors of this specific demographic in the AI era, we aim to contribute to a deeper understanding of the transformative forces at play in education and beyond.

## **Methodology**

### **2.1 Research Approach**

This study adopts a quantitative research approach to investigate the impact of Artificial Intelligence on motivation and productivity, with a specific focus on high school students. Through quantitative methods, we aim to systematically analyze data gathered through a structured survey to draw meaningful conclusions.

### **2.2 Sample Selection**

To ensure the representation of Hillsborough County high school students across various demographic backgrounds and school settings, we implemented a robust sample selection strategy. Specifically, a simple random sampling method was employed. Through this approach, we sought to minimize potential selection bias by randomly selecting participants from a diverse array of high schools within Hillsborough County. This ensured that our findings could be more confidently generalized to the broader high school student population within this geographical region.

### **2.3 Data Collection**

Data collection was conducted using a survey questionnaire specifically for high school students in Hillsborough County. The survey questionnaire comprised several distinct sections to address the central research objectives comprehensively.

- **Demographics:** The initial section of the questionnaire aimed to gather basic demographic information about the participants, such as age, gender, grade level, and academic interests. This allowed us to establish a clear profile of the sample population.

- **AI Interaction:** In the subsequent section, we delved into the extent and nature of participants' interactions with AI technologies. This section explored various aspects of AI engagement in their lives, including education, daily routines, and entertainment.
- **Perceived Impact:** The central focus of the questionnaire revolved around participants' perceptions of how their use of AI technologies affected their feelings of laziness. This section aimed to capture nuanced insights into their attitudes and experiences.

The survey was administered electronically, offering participants the convenience of responding online. This approach not only ensured the efficiency of data collection but also minimized potential biases introduced by in-person administration. Participants were guided through a series of questions and prompts, carefully crafted to elicit comprehensive responses that would provide valuable insights into their experiences and perspectives regarding AI.

#### 2.4 Ethical Considerations:

Throughout the research process, ethical considerations were paramount to protect the rights and privacy of all participants. Informed consent was a foundational principle, and all individuals, regardless of age, were required to provide their explicit permission through an informed consent form. For participants below the legal age of consent, parental consent was diligently obtained, underscoring our commitment to transparency and informed participation.

Confidentiality and anonymity were stringently upheld to safeguard individual responses from being traced back to specific participants. Participants were reassured that their input was treated with utmost discretion and that they had the right to withdraw from the study at any point without consequence. This rigorous adherence to ethical guidelines ensured that the research was conducted with the highest ethical standards.

#### 2.5 Data Analysis:

Upon the completion of data collection, the quantitative data obtained from the survey underwent thorough statistical analysis. This encompassed two primary types of analyses:

- **Descriptive Statistics:** Descriptive statistics, such as frequencies and percentages, were employed to provide a comprehensive summary of the collected data. These statistics allowed us to present a clear overview of participant responses and key trends within the dataset.
- **Inferential Tests: Chi-Square Test of Independence:** To examine the relationships between variables and identify statistically significant associations, we employed inferential tests. Specifically, the chi-square test of independence was utilized to assess the correlation between AI usage frequency and perceptions of laziness among high school students. This statistical approach enabled us to determine the presence and strength of associations within our data.

### **Results—3.1 Descriptive Statistics**

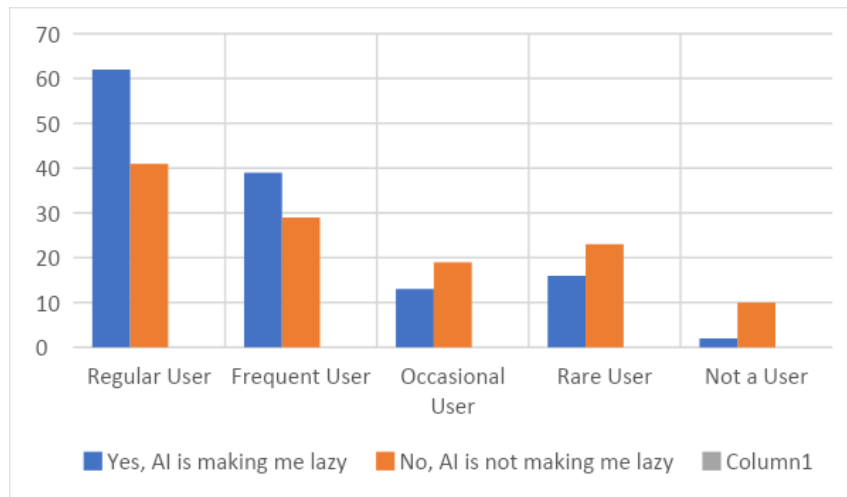
In this section, we analyzed responses from 254 high school students in Hillsborough County to gain insights into how AI integration in education may influence student motivation and productivity.

**Table 1:** Relationship Between AI Usage Frequency and Perceived Impact on Laziness

AI Usage Frequency	Is AI making you lazy?		Totals
	Yes	No	
Regular User	62	41	103
Frequent User	39	29	68
Occasional User	13	19	32
Rare User	16	23	39
Not a User	2	10	12
Totals	132	122	254

The following table (Table 1) provides a breakdown of participant responses, categorizing students based on their AI usage frequency and whether they perceive AI as making them lazy. This analysis reveals important insights into the interplay between the usage of AI and the perceived impact on the user’s laziness, which we will further discuss in the following sections.

**Figure 1:** Participants’ Perception of Impact of AI on their Laziness



The clustered histogram (Figure 1) illustrates the distribution of responses among high school students in Hillsborough County based on their AI usage frequency and the perception of AI's impact on laziness. Notably, students classified as "Regular Users" or "Frequent Users" of AI show a higher proportion (approximately 60% and 57%, respectively) perceiving AI as contributing to laziness, while "Occasional Users" and "Rare Users" exhibit a lower likelihood of holding this perception. These findings suggest that higher AI usage frequency may correlate with an increased likelihood of students viewing AI as a factor in reduced motivation, supporting our research hypothesis.

## 2.2 Inferential Statistics

Having examined the distribution patterns within the clustered histogram, it is evident that there are apparent differences in the perceptions of AI's impact on laziness across various AI usage

frequency groups. To actually assess the statistical significance of these observed differences and to determine whether they are indicative of a genuine association, a chi-squared ( $\chi^2$ ) test of independence is used.

The  $\chi^2$  test allows us to scrutinize whether there is a statistically significant relationship between AI usage frequency and the perception of AI's impact on motivation among high school students. In essence, it helps us ascertain whether the variations we observe in the histogram data are likely due to random chance or if they genuinely reflect a meaningful connection.

*Hypothesis*

$H_0$ : There is no association between the AI usage frequency and AI making a student lazy in the population of high schools in Hillsborough County.

$H_a$ : There is an association between the AI usage frequency and AI making a student lazy in the population of high schools in Hillsborough County.

*Significance Level:*

$\alpha = 0.05$

*Conditions:*

Random: A random sample of 254 high school students is used from Hillsborough County.

Independence: It is reasonable to assume that  $254 < 10\%$  of all high school students in Hillsborough County.

Large Counts: All expected counts are at least 5 (see table below):

**Table 2:** Expected Count of Relationship Between AI Usage Frequency and Perceived Impact on Laziness

AI Usage Frequency	Is AI making you lazy?		Totals
	Yes	No	
Regular User	53.52755906	49.47244094	103
Frequent User	32.33858268	32.66141732	68
Occasional User	16.62992126	15.37007874	32
Rare User	20.26771654	18.73228346	39
Not a User	6.236220472	5.763779528	12
Totals	132	122	254

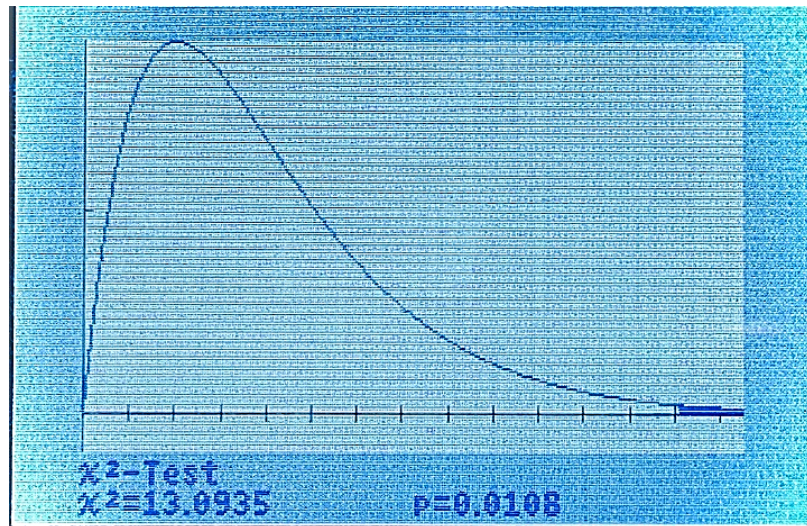
*Test Statistic*

$$\chi^2 = \sum \frac{(\text{observed count} - \text{expected count})^2}{\text{expected count}}$$

$$\chi^2 = 13.09$$

with a df (degree of freedom) of  $(5 - 1)(2 - 1) = 4$ .

**Figure 2:** Chi-Squared Distribution Plot with Degrees of Freedom (df) and P-Value



## Interpretation

### 4.1 Analysis

In the analysis of the survey data, a chi-squared test of independence was conducted to explore the relationship between participants' perceived impact of AI on laziness and the frequency of their AI usage. The chi-squared statistic value was found to be 13.09, with 4 degrees of freedom, and the significance level was  $p < 0.05$ .

This indicates that because the p-value of 0.010828 is less than the significance level of 0.05, we reject the  $H_0$  that there is no association between the AI usage frequency and the participants' perception of AI making them lazy in the population of high school students in the Hillsborough County. We have convincing evidence of an association between the AI usage frequency and participants' perception of AI making them lazy in the population of high school students in Hillsborough County.

### 4.2 Implications

The statistically significant association uncovered by the chi-squared test indicates that there is a notable correlation between participants' perceptions of AI making them lazy and how frequently they engage with AI. This statistical finding suggests that there is a meaningful connection between these two variables, but it is essential to delve deeper into this relationship for a more nuanced understanding.

Upon closer examination, it becomes evident that individuals who use AI more frequently are more inclined to report that AI is making them lazy. This implies that there may be underlying mechanisms at play. It is conceivable that those who engage with AI more frequently may rely on AI-driven solutions for a broader range of tasks, including those that could potentially be accomplished without AI. Consequently, a perceived decrease in self-initiative or motivation may result, leading to the conclusion that AI contributes to making students lazy.

Conversely, participants who use AI less frequently may not rely on it to the same extent for everyday tasks or problem-solving. For these individuals, AI might not have as substantial an

influence on their motivation or productivity, leading them to perceive its impact on laziness differently.

However, while this statistical correlation provides valuable insights, it is crucial to recognize that it does not establish causation. The correlation between AI usage frequency and perceived laziness does not inherently imply that AI directly causes laziness. It merely suggests an association between the variables, leaving room for various contributing factors and potential nuances within this relationship.

While the majority of our findings indicated a correlation between higher AI usage frequency and the perception of AI making students lazier, it is noteworthy that a subset of respondents who reported not using AI also expressed a similar sentiment. This intriguing observation suggests that factors beyond AI usage frequency may influence students' perceptions.

#### 4.3 Discussion

The statistical correlation uncovered in this study between the frequency of AI usage and perceptions of AI-induced laziness among high school students is a significant finding with implications for both education and technology. While this correlation underscores the complexity of the relationship between AI technology and human motivation, it is essential to consider potential contextual and psychological factors that may contribute to this association.

One possible interpretation of the correlation is that high school students who frequently engage with AI may rely on it for various tasks, including those that they could accomplish independently. This reliance on AI for routine activities might lead to a perceived decrease in self-initiative, as the convenience of AI solutions can sometimes substitute for the effort required to perform tasks manually. This scenario aligns with previous research that has raised concerns about technology's potential to foster passivity when misused.

Conversely, students who use AI less frequently may be more accustomed to engaging their problem-solving skills and self-initiative, as they tackle tasks without the aid of AI. As a result, they may be less likely to perceive AI as a contributing factor to laziness.

However, it is crucial to acknowledge the limitations of this correlation-based analysis. Correlation does not imply causation, and while there is a statistical relationship between AI usage frequency and perceptions of laziness, determining the direction of causality or identifying underlying mechanisms requires further investigation, as there could be the possibilities of other confounding variables in play.

Moreover, the interpretation of this correlation may vary depending on individual perspectives. Some students may view AI as a valuable tool that enhances their efficiency and frees them from mundane tasks, allowing them to focus on more creative or challenging endeavors. In contrast, others may perceive AI as a crutch that hinders their self-reliance and intrinsic motivation. Understanding these diverse viewpoints is essential for educators, policymakers, and parents as they navigate the integration of AI technology into the educational landscape.

#### 4.4 Limitations:

While this study offers valuable insights into the relationship between AI usage frequency and perceived laziness among high school students from Hillsborough County, several limitations should be considered when interpreting the findings.

- **Self-Reported Data:** One of the primary limitations is the reliance on self-reported data. Participants provided responses based on their perceptions and experiences, which can introduce response bias. High school students from Hillsborough County may have varying degrees of self-awareness and honesty when reflecting on their behaviors and attitudes. Additionally, social desirability bias may have influenced responses, leading participants to provide answers they believed were expected or socially acceptable.
- **Cross-Sectional Nature:** The study's cross-sectional design, which collected data at a single point in time, limits the ability to establish causality. While a correlation between AI usage frequency and perceived laziness was observed among high school students from Hillsborough County, this design does not allow for conclusions about the direction of causation or the temporal nature of the relationship. Longitudinal studies tracking changes in AI usage and perceptions over time within this specific demographic would provide a more nuanced understanding.
- **Limited Generalizability:** This study focused exclusively on high school students from Hillsborough County, and its findings may not be generalizable to other age groups, educational settings, or populations with different characteristics and contexts. Different regions, educational systems, or cultural backgrounds may exhibit distinct relationships between AI usage and perceived laziness.
- **Limited Contextual Exploration:** The survey did not delve deeply into the specific contexts in which AI was used or the types of tasks for which it was employed among high school students from Hillsborough County. Exploring these contextual factors could provide a more comprehensive understanding of how AI impacts motivation and productivity in this specific population.
- **Lack of Psychological Factors:** The study did not investigate psychological factors such as intrinsic motivation, self-efficacy, or attitudes toward technology in depth among high school students from Hillsborough County. These factors can significantly influence the relationship between AI usage and perceptions of laziness and warrant further exploration within this specific demographic.
- **Evolving AI Landscape:** The field of AI technology is dynamic and continuously evolving. The survey captured data at a specific point in time among high school students from Hillsborough County, and the impacts of AI on motivation and productivity may change as technology advances. Therefore, the study's findings may not reflect potential shifts in perceptions and behaviors over time.
- **Potential Confounding Variables:** While efforts were made to isolate the relationship between AI usage and perceived laziness among high school students from Hillsborough County, other unmeasured variables could be at play. Factors such as educational



approaches, parental influences, and peer interactions within this specific demographic may interact with AI usage to shape perceptions and behaviors.

- **Misreporting:** One limitation of this study is the unexpected finding that some respondents who reported not using AI still expressed perceptions of AI making them lazier. While this finding prompts intriguing questions about potential indirect exposure to AI or differing attitudes toward technology, our study did not delve deeply into these aspects.
- **Limited Qualitative Insights:** Unlike quantitative data, which can provide statistical associations, qualitative insights into participants' experiences were not obtained among high school students from Hillsborough County. Qualitative data could offer a deeper understanding of the underlying motivations and attitudes that contribute to the observed correlations.

While the findings of this study among high school students from Hillsborough County provide a valuable starting point for understanding the complex relationship between AI usage and perceptions of laziness, these limitations underscore the need for caution when interpreting the results, particularly in the context of this specific demographic.

## **Conclusion**

This study has endeavored to shed light on the intricate relationship between Artificial Intelligence (AI) usage frequency and the perceptions of AI-induced laziness among high school students in Hillsborough County. Our findings, although subject to certain limitations, offer valuable insights into the dynamics at play within this specific demographic.

The correlation identified between AI usage frequency and perceived laziness underscores the need for a nuanced understanding of how technology influences the motivation and productivity of high school students. It is clear that, among our participants, those who engage with AI more frequently are more inclined to report that AI is making them feel lazier. While this statistical association is significant, it is essential to remember that correlation does not imply causation. A host of contextual, psychological, and educational factors could contribute to this relationship.

In the educational landscape, where AI continues to play an increasingly prominent role, these findings raise important considerations for educators, parents, and policymakers. High school students are navigating a digital world where AI-driven tools and resources are readily available. Balancing the benefits of AI-enhanced learning with concerns about potential impacts on self-motivation and productivity is a multifaceted challenge.

Moving forward, it is imperative to recognize that technology, including AI, is a tool that can be harnessed in diverse ways. Educators and institutions should take a proactive approach in equipping students with the skills to critically engage with AI, encouraging them to leverage its potential while maintaining a sense of autonomy and self-initiative.

While this study contributes to the understanding of this complex relationship, it represents only one piece of a much larger puzzle. Further research is needed to explore the

underlying mechanisms, contextual factors, and psychological processes that shape the impact of AI on high school students. Longitudinal studies, qualitative investigations, and broader demographic analyses can provide deeper insights.

In conclusion, the influence of AI on the motivation and productivity of high school students is an evolving field of study with implications for education, technology, and society at large. Our findings emphasize the need for ongoing research and informed approaches to navigate the ever-changing landscape of AI in education. By fostering a balanced integration of AI technology and nurturing students' self-determination and intrinsic motivation, we can better prepare the next generation for the challenges and opportunities of an AI-augmented world.

### Works Cited

- Ahmad, S. F., Han, H., Alam, M. M., Rehmat, M. K., Irshad, M., Arraño-Muñoz, M., & Ariza-Montes, A. (2023). Impact of artificial intelligence on human loss in decision making, laziness and safety in education. *Humanities and Social Sciences Communications*, *10*(1), 1–14. <https://doi.org/10.1057/s41599-023-01787-8>
- Cellan-Jones, R. (2014, December 2). Stephen Hawking warns artificial intelligence could end mankind. *BBC News*. <https://www.bbc.com/news/technology-30290540>
- Jose G. Sison, A., Daza, M. T., Gozalo-Brizuela, R., & Garrido-Merchán, E. C. (2023). ChatGPT: More than a Weapon of Mass Deception, Ethical challenges and responses from the Human-Centered Artificial Intelligence (HCAI) perspective. *Arxiv*. <https://doi.org/10.48550/arxiv.2304.11215>
- Khanzode, K. C. A., & Sarode, R. D. (2020). ADVANTAGES AND DISADVANTAGES OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING: A LITERATURE REVIEW. *INTERNATIONAL JOURNAL of LIBRARY and INFORMATION SCIENCE (IJLIS)*, *9*(1), 30–36. [https://iaeme.com/Home/article\\_id/IJLIS\\_09\\_01\\_004](https://iaeme.com/Home/article_id/IJLIS_09_01_004)
- Lin, C.-C., Anna Y.Q. Huang, & Owen H.T. Lu. (2023). Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. *Smart Learning Environments*, *10*(1). <https://doi.org/10.1186/s40561-023-00260-y>
- Pomerol, J.-C. (1997). Artificial intelligence and human decision making. *European Journal of Operational Research*, *99*(1), 3–25. [https://doi.org/10.1016/s0377-2217\(96\)00378-5](https://doi.org/10.1016/s0377-2217(96)00378-5)
- Starnes, D. S. (2019). *Practice Of Statistics*. W H Freeman.
- Stokel-Walker, C., & Van Noorden, R. (2023). What ChatGPT and generative AI mean for science. *Nature*, *614*(7947), 214–216. <https://doi.org/10.1038/d41586-023-00340-6>

## **Balancing Pixels and Performance: Understanding the Dual Impact of Video Games on Students' Academic and Cognitive Growth By Otávio Battaglia Vieira**

### **Abstract**

This article offers a review of various articles on the impact of video games (VGs) on the academic performance and cognitive abilities of students. The available literature presents multifaceted results, with some studies pointing out the possible detrimental effects of VGs, while others their potential benefits. Through a balanced examination, the article concludes that the impact of VGs is not completely good or bad, but it depends on various factors, like, for example, the amount of time spent playing VGs. It also advocates a balanced approach to the topic, aiming to mitigate the negative effects while maximizing the benefits, and it also emphasizes that further research is needed for a conclusive understanding of the topic.

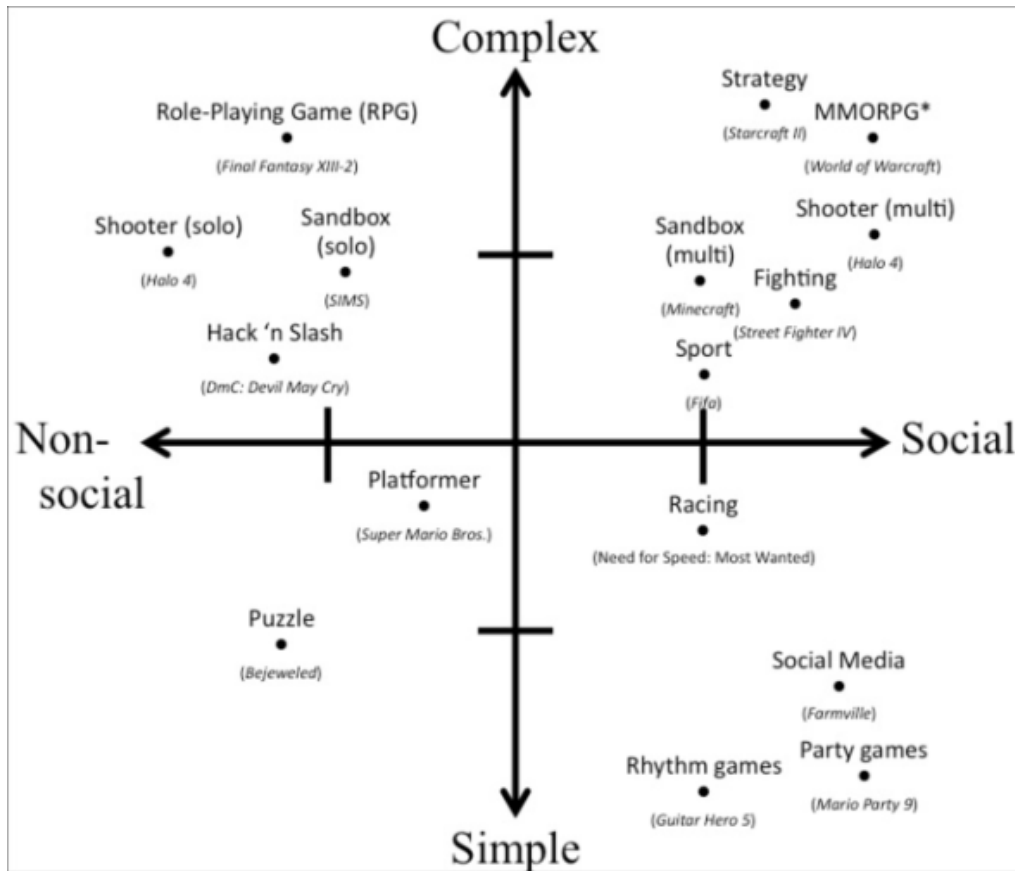
### **Introduction**

Video games have become more prevalent in society. With the advent of the internet and the smartphone, they are literally at the palm of our hands, anytime and everywhere. They grab the attention of everyone, with no age boundaries. And VGs have also become a way of life as it has risen to the status of sport (e-sports) and these athletes make a living like any other athlete. So VGs have really become ingrained in our modern way of life. As much as 90% of American students engage with video games in some capacity, yet their impact on academic performance and cognitive abilities remains uncertain due to conflicting research findings. This article aims to provide a review of studies on the influence of VGs on academic performance and also on cognitive skills such as attention, memory, and problem-solving abilities. Through an analysis of available literature, it is evident that while many studies suggest that video games have detrimental effects in those aspects, other studies conclude with a more optimistic view of the topic, highlighting that it has positive effects. This article emphasizes the importance of striking a balance between VG engagement and academic pursuits to maximize the benefits and minimize any potential drawbacks.

### **Background–2.1 A digital generation, the rise of VGs**

Since the creation of the first video game console, Atari, in the early 70s, they have become more popular each year that passes. With the advancements in computer technology, the advent of the internet and of the smartphones, anyone can play VGs anytime and everywhere. Nowadays, VGs are much more than a hobby; they have become a mainstream cultural phenomenon and have also risen to the status of sport with athletes and championships that are broadcasted all over the world. Approximately 90% of American teens report playing VGs, ranging from simple mobile games to computer and virtual reality, appealing to a huge spectrum of the population. This allows students to choose from a range of different genres to find a game that suits them, further contributing to its spread. The graph below (Figure 1) shows the scope of genres of video games from complex to simple and from social to non-social.

Figure 1: Range of VGs variability



This breadth of possibilities was important for the rise of the video game industry, and it led to gaming communities, which also played an important role in engaging players. These communities offer a space where people with similar interests can interact and engage, offering a place where people can socialize, collaborate, compete, and create a sense of identity and belonging.

## 2.2 Available Data on VGs and academic performance

The relation between VGs and academic performance is an uncertain topic, while some studies suggest that VGs cause a decline in grades and academic engagement, others suggest that it increases students' engagement and enhances problem-solving skills.

### **Negative Effects**

In this section we comment on the negative findings of the studies analyzed. As we will see, some studies show causation between excessive video gaming and negative effects, without necessarily showing causation. Any activity in which you spend a lot of time, by yourself, sitting down and with constant brain stimulus could have the same effects. We only have 24 hours in a day, so the more we dedicate ourselves to one thing, the less we spend on other things and that

such behavior can lead to negative effects in other areas. Here are the 7 main negative effects on the studies analyzed:

### 3.1 Academic Performance

Negative impacts on academic performance have been observed in various studies. Anand (2007) discovered a negative correlation between the time spent playing VGs and GPA, as well as SAT scores. Other researchers have identified that with more time spent playing VGs, students had a decline in homework completion, reading, and other academically beneficial activities (Gentile et al., 2004).

### 3.2 Cognitive and Behavioral Issues

Excessive VG playtime can lead to various cognitive and behavioral problems. Swing et al. (2010) found that high exposure to VGs is associated with attention problems in children and adolescents. In extreme cases, VGs may contribute to the development of pathological gaming behaviors, characterized by loss of control over gaming habits and subsequent negative impacts on daily life (Gentile et al., 2011).

### 3.3 Physical Health

The sedentary nature of video gaming might lead to negative physical health outcomes. Prolonged playing and screen time has been linked to obesity, especially in children and adolescents (Vandewater et al., 2004). The focus on screen-based entertainment can displace physical activities, contributing to an unhealthy lifestyle.

### 3.4 Social Skills and Isolation

Excessive gaming may result in decreased social interaction and development of social skills, especially face-to-face communication. While online gaming communities provide a form of social interaction, they may not substitute real-world social experiences, leading to social isolation, since the time spent on the internet had a negative correlation to participants communication with family members, reduction in the size of their social circle and increase in diseases such as depression (Kraut et al., 1998).

### 3.5 Aggression and Desensitization

Some research has connected violent VG content with increased aggression in players. For example, Anderson et al. (2010) have found that exposure to violent VGs may increase aggressive thoughts, feelings, and behaviors and a decrease in empathy, possibly through desensitization to violence. As the table below shows (Figure 2), hostility increases with higher exposure to violent VGs, even among the group of lowest hostility individuals.

Figure 2: Relation between hostility and exposure to VGs

Hostility- quartiles	Exposure to violent VGs- quartiles				Average
	Lowest exposure	Low exposure	High exposure	Highest exposure	
Lowest hostility	4%	26%	15%	38%	<b>14%</b>
Low hostility	16%	33%	27%	58%	<b>31%</b>
High hostility	24%	42%	44%	54%	<b>41%</b>
Highest hostility	28%	37%	58%	63%	<b>50%</b>
<b>Average</b>	<b>14%</b>	<b>34%</b>	<b>39%</b>	<b>55%</b>	

### 3.6 Sleep Disruption

Extended late-night gaming sessions may lead to sleep disruptions. A study by Weaver et al. (2010) linked nighttime video game playing with a rise in cognitive awareness, causing slight difficulties in falling asleep and maintaining a healthy sleep schedule.

### **Positive Effects**

The list of positive effects is a little bit shorter, with 6 positive findings. These studies use far less the word “excessive” so here we are talking about studies that look at VGs as a moderate or light activity and try to show that it can bring positive effects. Some studies show that VGs are not demons or drugs, as they grab our attention, they may be very useful for certain activities and for certain people. Here are the 6 main positive effects from the studies analyzed:

#### 4.1 Cognitive Development

Contrary to the negative findings, there are numerous studies that emphasize the positive effects of VGs on cognitive development. Green and Bavelier (2003) discovered that action video games can improve visual attention and spatial-temporal reasoning. Granic et al. (2014) noted that strategic games, including role-playing games, enhance problem-solving and critical thinking skills. Boot and Kramer (2008) compared the attention, memory, and executive control of expert gamers to non-gamers, revealing cognitive advantages in the gaming group. They observed that the experts could track moving objects better, detect changes in objects stored in short term memory, switch from task more efficiently and mentally rotate objects more efficiently.

#### 4.2 Educational Enhancement

Several researchers have explored the potential of VGs as educational tools. Squire (2003) highlights the success of using games in classrooms to reinforce traditional learning material, fostering engagement, and promoting a deeper understanding of complex subjects. VGs can serve as supplementary learning resources, aiding in subjects ranging from mathematics to history, as the table below (Figure 3) shows, VGs are a highly efficient tool for education, the

table show the quality of the E-learning based of the tool used in an elementary school environment.

<b>Evaluation dimension</b>	<b>Mean</b>	<b>Standard deviation</b>
1. Teaching Contents (Content, total score 21)	19.6	1.08
2. Learning Directions (Navigation, total score 19)	16.0	2.10
3. Teaching Design (Instructional design, total score 43)	41.3	1.63
4. Teaching Media (Instructional media, total score 21)	19.0	1.10
Total score (Total, total score 104)	95.9	4.37

Figure 3: Evaluation of teaching material result from E-learning quality

#### 4.3 Motor Skills and Hand-Eye Coordination

Many studies, including those by Lukasz Borecki (2013), have shown that certain VGs, especially those requiring precise timing and control, can improve hand-eye coordination and fine motor skills. The table below (Figure 4) from the study shows the relative performance of Players and Non-players on several fine motor skills and coordination tests.

Figure 4: Motor skills test made with VG players and Non VG players

<b>Test</b>	<b>Players</b>	<b>Non-players</b>
Aiming (point index)	9.2 ± 9.0	5.0 ± 0.8
Steadiness (tremor)	6.5 ± 0.6	8.9 ± 0.8
Total time of error(s)	1.6 ± 0.6	2.8 ± 0.6
Number of errors	13.6 ± 0.3	20.4 ± 2.2
Total time of task(s)	14.6 ± 2.9	32.1 ± 4.5
Wrist speed ability(s)	228.2 ± 7.3	183.2 ± 9.9

#### 4.4 Therapeutic uses

VGs are also successfully used in rehabilitation of patients with physical disabilities and in treatment of mental health issues, serving as a motivation and progress tracking tool (Ferguson & Olson, 2013).

#### 4.5 Social Skills and collaboration

Contrary to the popular belief that gaming always leads to social isolation, some research indicates that co-op (cooperative) multiplayer games foster teamwork, communication and empathy amongst those involved (Gee, 2003). Not only that but friendships may be facilitated through online gaming communities.



#### 4.6 Creativity and Innovation

Creative games that allow players to build and manipulate the virtual world may enhance creative and innovative thinking. Examples of VGs like Minecraft provide opportunities for imaginative play and development of design and engineering skills (Barr, 2017).

#### **Conclusion**

The impact of VGs on students' academic performance and cognitive skills is a multifaceted discussion. While there is clearly a correlation between excessive gaming and negative effects - ranging from declines in academic performance to the sleep quality - there is also other studies that suggest that gaming or VGs also have a positive effects, including benefits in cognitive development, education enhancement, improved motor skills and hand-eye coordination, therapeutic applications and even improvement in social skills and creativity.

As we know, video games have become a part of modern life and we must learn to live with them and try to make the best out of their attributes. We have seen that the effects of gaming may vary from person to person and from situation to situation. In general, what the studies mentioned in this article show is that excessive gaming is probably going to bring negative consequences and should be avoided. On the other hand, they also show that VGs can also be beneficial to personal and cognitive development. So we can conclude that video games are neither good or bad; rather, their impact largely depends on the context in which they are consumed, the time played and the genres chosen. Balance is probably the key to a healthy relationship with VGs, for getting the positive effect and mitigating the negative ones.

In summary, this article calls for a balanced perspective that recognizes both the potential risks and the benefits associated with video games. Further research is needed to improve our understanding of the impact of GV's on the academic and cognitive performance of students, but for now, the key word when we talk about gaming and VGs is balance.

## Works Cited

- Anand, Vivek. "A Study of Time Management: The Correlation between Video Game Usage and Academic Performance Markers." *CyberPsychology & Behavior*, vol. 10, no. 4, Aug. 2007, pp. 552–59, <https://doi.org/10.1089/cpb.2007.9991>.
- Anderson, Craig A., et al. "Violent Video Game Effects on Aggression, Empathy, and Prosocial Behavior in Eastern and Western Countries: A Meta-Analytic Review." *Psychological Bulletin*, vol. 136, no. 2, Mar. 2010, pp. 151–73, <https://doi.org/10.1037/a0018251>.
- Barr, Matthew. (2017). Video games can develop graduate skills in higher education students: A randomised trial. *Computers & Education*. 113. 10.1016/j.compedu.2017.05.016.
- Boot, Walter R., et al. "The Effects of Video Game Playing on Attention, Memory, and Executive Control." *Acta Psychologica*, vol. 129, no. 3, Nov. 2008, pp. 387–98, <https://doi.org/10.1016/j.actpsy.2008.09.005>.
- Borecki, Lukasz, et al. "Computer Games and Fine Motor Skills." *Advances in Experimental Medicine and Biology*, vol. 755, June 2012, pp. 343–48, [https://doi.org/10.1007/978-94-007-4546-9\\_43](https://doi.org/10.1007/978-94-007-4546-9_43).
- Drummond, Aaron, and James D. Sauer. "Video-Games Do Not Negatively Impact Adolescent Academic Performance in Science, Mathematics or Reading." *PLoS ONE*, edited by Chris Chambers, vol. 9, no. 4, Apr. 2014, p. e87943, <https://doi.org/10.1371/journal.pone.0087943>.
- Ferguson, Christopher J., and Cheryl K. Olson. "Video Game Violence Use among 'Vulnerable' Populations: The Impact of Violent Games on Delinquency and Bullying among Children with Clinically Elevated Depression or Attention Deficit Symptoms." *Journal of Youth and Adolescence*, vol. 43, no. 1, Aug. 2013, pp. 127–36, <https://doi.org/10.1007/s10964-013-9986-5>.
- Gee, J. P. (2003). What Video Games Have to Teach us about Learning and Literacy? *Computers in Entertainment (CIE)*, 1, 20-20. <http://dx.doi.org/10.1145/950566.950595>
- Gentile, D. A., et al. "Pathological Video Game Use among Youths: A Two-Year Longitudinal Study." *PEDIATRICS*, vol. 127, no. 2, Jan. 2011, pp. e319–29, <https://doi.org/10.1542/peds.2010-1353>.
- Gentile, Douglas A., et al. "The Effects of Violent Video Game Habits on Adolescent Hostility, Aggressive Behaviors, and School Performance." *Journal of Adolescence*, vol. 27, no. 1, Feb. 2004, pp. 5–22, <https://doi.org/10.1016/j.adolescence.2003.10.002>.
- Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist*, 69(1), 66–78. <https://doi.org/10.1037/a0034857>
- Granic, Isabela, et al. "The Benefits of Playing Video Games." *American Psychologist*, vol. 69, no. 1, Jan. 2014, pp. 66–78, <https://doi.org/10.1037/a0034857>.
- Green, C. Shawn, and Daphne Bavelier. "Action Video Game Modifies Visual Selective Attention." *Nature*, vol. 423, no. 6939, May 2003, pp. 534–37, <https://doi.org/10.1038/nature01647>.

- Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukophadhyay, T., & Scherlis, W. (1998). Internet paradox: A social technology that reduces social involvement and psychological well-being? *American Psychologist*, 53(9), 1017–1031.  
<https://doi.org/10.1037/0003-066X.53.9.1017>
- Lu, Chow-Chin, and Shu-Li Jeng. “Developing Digital Game Based on the Conception of Insects (DGBI) to Test Elementary Student’s Insect Conceptions.” *Creative Education*, vol. 03, no. 08, 2012, pp. 101–10, <https://doi.org/10.4236/ce.2012.38b022>. Accessed 22 Apr. 2022.
- Squire, Kurt. (2003). Video Games in Education. *International Journal of Intelligent Simulations and Gaming*. 2. 49-62. 10.1145/950566.950583.
- Swing, E. L., et al. “Television and Video Game Exposure and the Development of Attention Problems.” *PEDIATRICS*, vol. 126, no. 2, July 2010, pp. 214–21, <https://doi.org/10.1542/peds.2009-1508>.
- Vandewater, Elizabeth & Shim, Mi-suk & Caplovitz, Allison. (2004). Linking obesity and activity level with children’s television and video game use. *Journal of adolescence*. 27. 71-85. 10.1016/j.adolescence.2003.10.003.
- Weaver, Edward, et al. “The Effect of Presleep Video-Game Playing on Adolescent Sleep.” *Journal of Clinical Sleep Medicine: JCSM: Official Publication of the American Academy of Sleep Medicine*, vol. 6, no. 2, Apr. 2010, pp. 184–89, [pubmed.ncbi.nlm.nih.gov/20411697/](http://pubmed.ncbi.nlm.nih.gov/20411697/).

## **Bangalore's Lost Identity: Technology and Change Over Time By Atheeth Ravikrishnan**

### **Abstract**

Starting in the late 20th century, India's economy was characterized by a strong emphasis on private property, free market, and free trade, coinciding with what some experts have described as a global "neoliberal" trend. In particular, Bangalore, the largest city of the southern Indian state of Karnataka, once viewed as a "supposedly idyllic and verdant garden city," became a locus for technology companies to settle. This paper provides an overview of the political and economic developments within the technological realm, focusing on class struggle and human demographic shifts from early modern colonial history to independence. In the final section, this study concludes that the tectonic shifts brought about by the "financial boom" have withered the city's soul away into an unrecognizable counterpart.

### **Introduction**

Bangalore was once known as the "garden city" of India.<sup>155</sup> As Bangalore became Bengaluru, what was once a verdant forest, lush with overarching canopies and vineyards, transformed over decades into a city defined by its towering concrete jungles. During the time that I lived in the city from 2006 to 2017 as a young boy, I witnessed traditional institutions revamp themselves to incorporate modern technologies into their ways of life. In my many travels back and forth over the years, I have seen the auto-rickshaws (autos for short), a symbol of the Indian working class, join the ride-share app boom. The wait by the side of the road to hail a free auto, spending numerous minutes debating over the price, and ultimately riding became irrelevant when both Uber and India's own Ola began to include these rickety machines as part of their lineups. Anecdotes like these changes barely stretching two decades, stem from a singular idea: Bangalore's tech boom. With the pool of tech companies terraforming its landscape and economy, Bangalore has undergone a tectonic shift. Scholars and journalists alike have commented on this moment as emblematic of a more significant global trend, which they describe as "neoliberalism." Today, numerous business and apartment complexes have devoured Bangalore's evergreen earth. Yet, with the generation of wealth stemming from new technologies and the widening of income inequality among classes, I argue that the city's identity has been lost. In this paper, I will explore how Bangalore's financial boom revolutionized its scenery while altering its identity.

### **Colonial Background**

Before delving into the primary focus of this paper, Bangalore's economic explosion and its wide-scale consequences, I will quickly brush over some of India's colonial history. Any

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<sup>155</sup> The legendary title appears to trace back to a saying from Krishna Raja Wodeyar, the 24th Maharaja, the Sanskrit title for a "great ruler" or "king" of the Kingdom of Mysore.

history of India, Bangalore included, must be traced back to colonialism.<sup>156</sup> Approximately 526 years ago, Portuguese explorer Vasco Da Gama voyaged and uncovered the sea route to India. The floodgates were opened, and numerous European nations built new trade networks through the sea. In 1600, the British East India Company (BEIC) was established to create a strong trade network between the British Isles and the Indian Subcontinent. Slowly, the BEIC established more significant control over the territory, winning decisive victories and overthrowing previous regimes of the numerous regional kingdoms of India. With subsequent legislation, such as the India Acts, passed by the British Parliament, the British government started to assert more direct control over Indian territory.

The following two centuries of Bangalore and Indian history are a story of the British asserting more and more control until we arrive at a year many historians see as a turning point in modern Indian history: 1857. At this time, Sepoy soldiers, the East India Company guards, began to revolt in a mutiny, protesting against cow and pig skin used in gun cartridges, a religious taboo for both Hindus and Muslims. The sepoys eliminated all of their British officers. Eventually, the mutiny came to a halt by British forces. Angered by the protest, the British parliament destroyed the BEIC and adopted India under its massive colonial banner, creating a new state: the British Raj.

Bangalore became a central hub for administration for the South Indian sector of the British Raj. Since the old Kingdom of Mysore, the city of Mysore has been the primary stomping ground for the millennia of kingdoms that have come and gone with the sands of time. With the British arrival and their subsequent exposure to malaria, the colonizers relocated to Bangalore's more pleasant environment, one with a warm climate and less humidity. Once in the city, they established their own administrative offices, with numerous military settlements dotting the landscape.<sup>157</sup> Understanding Bangalore's occupation by the British due to ecological reasons and its transformation over the early modern period provides a crucial background for thinking critically about the tumultuous transformation that has occurred in the past few decades.

### **Early Economy: Textile Mills**

A colony for over 200 years, Bangalore's early economic practices were directly tied to supporting British interests. Late 19th-century and early 20th-century Bangalore can be defined by a critical financial venture: textile mills. Numerous mills dotted the landscape, ranging from Bangalore Woolen, Silk, and Cotton Mills to Maharaja of Mysore Mills (J. Nair, 81). These mills represented the backbone of early Bangalore economies. With British interest in India inextricably linked to the rapacious desire to extract resources not found on European soil, they installed numerous mills for this very purpose. Essential textiles like cotton and silk proved to be

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<sup>156</sup> Mike Davis is one prominent global historian who has focused extensively on the disastrous effects of British colonialism on India and the Mysore Province, particularly in his book *Late Victorian Holocausts: El Niño Famines and the Making of the Third World*.

<sup>157</sup> This information came out of the AP World History textbook written by: Jody Janis, David Brian Lasher, Amie La Porte-Lewis, Kevin Lewis, Jamie Oleson, Thomas J. Sakole, Clara Webb

of great interest to the British Raj. With millwork being such a big part of the early economy, it affected the demographics of Bangalore. Workers were diverse: they were made of a mixed group of laboring poor and head load workers (J. Nair, 81). Each factory occupied its district. With the transfer of workers throughout these areas, communities increased in size.

Textiles became the primary economic source of Bangalore. Before big tech, Bangalore's textile industry contributed to many of the early immigrants from across India entering its borders. It wasn't just textiles that carried a majority of the load. The entirety of Bangalore existed as one major industrial plant. From aircraft to steel tools—Hindustan Machine Tools (1955), for example—immigrants in other parts of the nation found refuge in the work. This boom in immigration served as a precursor to what would eventually happen with information technology (IT).

### **20th Century Nationalism and Neoliberalism**

As the ancient met the modern, a new theory rose up and began to cement its grip on the world's economies. This idea, perpetuated by the leading capitalist nations in the world, came to a head in the late 20th century. The notion of hyper-capitalism, when a government allows independent entrepreneurs to possess the liberty to pursue their business interests in a speedy, intense exchange of capital (i.e., goods, money, people, etc.), spread across the world. Head figures like former US president Ronald Reagan and former British prime minister Margaret Thatcher, using their policies such as Raeganomics, opened up a new era in capitalism. Perpetuated by new free global economic policies in the 1990s, neoliberalism soon snuck its way into India (Harvey, 1-30)

While not exclusive to Bangalore or India in general, for that matter, the doctrine of neo-liberalism pervades through the rise and notoriety of Bangalore on the global stage as a technological hub. It outlines how a government constructs a more open economy with little regulation. In the eyes of neo-liberal policymakers, regulation degrades money as inflation becomes the primary villain (Harvey). Towards this end, neo-liberalist governments aim to eliminate inflation and bring value back to the currency.

There have been marquee class developments with this economic shift in Bangalore's boundaries, transforming the once "garden city" into the Silicon Valley of the East (Patni). This new age of tech and internet moguls primarily facilitated the creation of a new bourgeoisie. This "boomtown bourgeoisie" (Srinivas), while unique in its design, has specific actions that are antithetical to modern growth. The rise of secularism worldwide marked the transition into the modern age. According to Tulasi Srinivas, the secular turn is no different for India, where politicians have de-emphasized religion to an extent for decades. At the same time, Bangalore's bourgeoisie and the money they generated paradoxically facilitated the construction of religious structures and the increased celebration of religious activity. This new bourgeoisie, whose houses have been paid for by the fruits of innovative and futuristic tech, has been responsible for increased traditionalist activities (Srinivas).

It was when India embraced neoliberalism that the “new” Bangalore was born. The adoption of neoliberalism can be seen in the policies targeting land acquisition for companies. Through acts like the Land Acquisition Act (LAA) and the Karnataka Industrial Areas Development Act (KIADA), IT companies were able to acquire areas away from the risky process of the market (Gosh). Along with this, the Bangalore Development Authority (BDA), a central figure in Bangalore’s makeover, asserts that “one must offer optimal conditions for IT Companies...” (Gosh). Transforming into the home of internet millionaires, Bangalore became the tech hub that linked South Asia with the rest of the world.

Bangalore’s character, its verdant nature, facilitated it as a perfect landing zone for all the big IT companies. Even before the Silicon bubble, Bangalore already possessed the best education, skills, and talent facilities. With its previous infrastructure, IT managed to find an easy, comfortable home in the landscape of Bangalore. Mixing IT’s discovery of a new home with the 1990s, the start of the free economy philosophy led by India's ruling class, tech had all the necessary tools to flourish in Bangalore.

### **Lost Identity**

With such a large economic shift, it was only natural that identity, too, would be altered. Bangalore was originally a verdant garden city. Lush trees lined the streets; and numerous shiny lakes dotted the terrain. From my experience living in the town, I would be hard-pressed to find an undisturbed area of greenery.. The transformation was so quick that Bangalore became entirely alien from its older generation. I have had family and teachers who lived in Bangalore before the “neo-liberalist shift.” They describe the city with pangs of nostalgia as a stunning, arching canopy and a calmness engulfing it. Due to neoliberalism, the original identity of the city has been lost to time, existing only as memories.

Alas, a city's identity is built on its citizens' backs. The primary issue, or more of a change, is that Bangalore's local population—the Kannada-speaking persons—is decreasing yearly. Spending 13 years of my childhood there, I can attest to this. In the schools or the apartments, it was primarily migrants from Kashmir to Kanyakumari, coming for tech work, then the indigenous population. Usually, the local population made up much of the working class in cities. However, as the tech industry drove up the real estate prices and living expenses, the native middle-class population was slowly pushed aside, and the influx of migrants from all over the country took their place in the city’s heart. With all this change, a new kind of culture has bloomed in Bangalore. This culture, less about ethnicity and race, blossomed from the modern-day tech market. A young, “hip” population of software engineers constructed a new city lifestyle not dissimilar from the numerous other modern city centers around the globe.

However, even with all the tech, even with all the change, Bangalore still is a “medium city. Unlike its peers in Delhi and Mumbai, it hasn’t reached the point of becoming a “maximum city” (Srinivas), and Bangalore could’ve reached this status. Although, in its attempt to become a “maximum city,” Bangalore has lost its original roots.

It can also be noted that Bangalore's shift is also clearly orientated to Western markets. What I mean by that is the "tech" of Bangalore primarily originated in the United States. Though numerous Indian companies and startups exist—especially as the years go on—Western companies dominate Bangalore's market. India and the United States economy evokes Gayatri Spivak's essay, *Can the Subaltern Speak*, where she outlined the Eurocentric position emerging from a debate between two French intellectuals, Gilles Deleuze and Michel Foucault, that assumed that there was no longer a need for intellectuals to represent the people, that the subaltern could now speak for themselves. This Western-orientated approach can be extrapolated and applied to Bangalore's history. In Spivak's essay, she describes how it is still essential for the intellectual to be responsible for representing "subalterns." Perhaps the most difficult question to pose as an aspiring historian is locating the agency in the narrative I have reconstructed: who is responsible for this tectonic shift, and just how bad is it? By studying how such Western developments affect the native population and by taking Indian scholars' works on this topic seriously, we can grasp a better understanding of the effects of the "tech boom" from a more native people's point of view.



### Work Cited

- Asha Ghosh. "Banking on the Bangalore Dream." *Economic and Political Weekly*, vol. 41, no. 8, 2006, pp. 689–92. *JSTOR*, <http://www.jstor.org/stable/4417867>. Accessed 14 Oct. 2023.
- Davis, Mike. *Late Victorian Holocausts: El Niño Famines and the Making of the Third World*. Verso Books, 2002.
- Nair, Janaki. *The Promise of the Metropolis: Bangalore's Twentieth Century*. Oxford UP, USA, 2005.
- Ranganathan, Malini. "Rule by difference: Empire, liberalism, and the legacies of urban "improvement"." *Environment and Planning A: Economy and Space* 50 (2018): 1386 - 1406.
- Spivak, Gayatri Chakravorty. "Can the Subaltern Speak?" *Die Philosophin*, vol. 14, no. 27, Philosophy Documentation Center, Jan. 2003, pp. 42–58.  
<https://doi.org/10.5840/philosophin200314275>.
- Srinivas, Tulasi. *The Cow in the Elevator: An Anthropology of Wonder*. Duke UP, 2018.
- Thompson, Edward Palmer. *The Making of the English Working Class*. IICA, 1963. *Travel tips & Articles Bangalore - KLM Norge*. (n.d.).  
<https://www.klm.no/travel-guide/inspiration/bangalore-the-garden-city-of-india>

# **The Impact of Cultural Factors on Immigrant Parents' Access to Disability Care for Their Disabled Children in the United States By Angelina Shi**

## **Abstract**

Immigrant parents face a multitude of challenges when navigating a healthcare system they are unfamiliar with. This study examines the impact of economic, cultural, and social barriers on immigrant parents' access to disability care for their children with intellectual and developmental disabilities (IDD) in the United States. Five immigrant parents living in South Florida participated in semi-structured interviews. The interviews revealed that parents must continuously advocate for their child's care to ensure they receive care from service providers that meet their child's needs, which left some parents unable to receive adequate care due to ineffective communication between service providers and the parent caused by lack of accommodations. Service providers must be more culturally sensitive and accommodate the needs of immigrant parents to facilitate effective communication, helping children with IDD receive adequate care. The research emphasizes the need for more inclusive and culturally sensitive services in the United States to ensure the well-being of children with IDD in immigrant families.

## **Introduction**

Many people immigrate to America to find a better future, not only for themselves, but for their children to have a better life than they've had, but does the American dream apply to their disabled child? People with intellectual and developmental disabilities (PIDD) are just as capable as neurotypical people but if parents have difficulty accessing disability services due to language barriers, cultural perceptions, and lack of support from communities (i.e., family, friends, support groups), it is illogical to think that PIDD will be able to excel in a country, even if disability services are available. Immigrant parents must be provided with sufficient accommodations because it is not only the presence of disability services, but also the parent's ability to utilize these services to its full capacity, that encourages the thriving futures of disabled children in America. This leads the researcher to question: How do cultural factors affect immigrant parents' access to disability care in the United States?

## **Literature Review**

### **Cultural Values and Stigma Around Disability**

The disability services an intellectually disabled child receives are heavily dependent on the family's cultural values and stigmas as they affect how the family views disability services. Many East Asian American families felt rejected by professionals, friends, and family because their child was intellectually disabled (Cheatham & Zeng 210; Kang-Yi et al. as cited by Dababnah & Kim 309; Zheng and Zheng as cited by Jiang et al. 1182) which decreased the chances of parental involvement in their intellectually disabled child's education (Deng et al, 2919). Partnered with Confucius's ideas that their child's disability was the 'punishment of God'

because of something the parent had done in a past life, (Zhang cited by Rosen & Zhang 1120) families with intellectually disabled children struggled with both cultural ideas from their home country and people from their cultural community in the United States not accepting them, causing the family to isolate their disabled child and themselves because of the disconnection to their culture. The stigma within East Asian American families regarding disability and its correlation with decreased involvement in disability care indicates the fear of loss of face (loss of respect in the community). Although families were uncomfortable with interactions with people, they shared a culture with, Korean American families, “felt more comfortable bringing their child into public in the U.S, due to their perception that non-KAs have more positive views toward people with disabilities compared to KAs” (Dababnah & Kim 313-314). At the same time, n et al. explain families reduced or cut off social relationships with others, due to both involvement with and providing services to their disabled child and embarrassment of their disabled child’s behaviors (339). The prevalence of feelings of discomfort in East Asian families shows the fear that their extended family would not understand and/or would want to fix their child due to their child’s deviation from social norms. Similarly, Gannotti et al. found that Latino parents “endorsed the notion of *añoñar* (pampering, nurturing); parents must create a smooth, pleasant, and social environment for their children, eliminating cause for emotional conflict and protecting their children from illness or injury” (as cited by Cohen 4) which may contribute to isolation in Latino families due to extended families’ misconceptions of disability. Despite the different reasons why families face isolation with an intellectually disabled child, Rosen & Zhang explain that only when parents give up their cultural stigmas regarding disability, then “can the children be treated as peers without disabilities, and have the opportunity to no longer be hidden at home, but to venture outside of the protective family environment, to go to the school, and to participate in the community” (1120).

### **Cultural Sensitivity and Socioeconomic Factors**

Cultural perceptions and socioeconomic factors are crucial to understanding how to make disability care more accessible and reliable to meet the needs of immigrant parents of children with intellectual disabilities (Gregoire 39). Haitian parents mentioned “having to work multiple jobs and having insufficient time to come to school, being unable to communicate effectively with school personnel in the absence of interpreters and lacking knowledge of the resources available to them” (Gregoire 115). Even with interpreters present, Riley explains, “Due to the shortage of bilingual special educators, school districts often hire interpreters who are fluent in the language but may not have knowledge of the vocabulary related to the field of special education” (as cited by Lo 17-18). Lack of confidence in their English proficiency is also a factor in immigrant parents’ ability to access disability care as a Korean mother who immigrated to the U.S. for her intellectually disabled child said she utilized disability services in Korea but after she moved to the U.S., she wasn’t confident in her English proficiency and she wasn’t aware of the resources available, so she only sent her son to public school. One Chinese-American parent, although fluent in English, still experienced misunderstandings with classroom teachers because

of cultural differences that led to different goals and perceptions of disability, even though the parent, “felt strongly that his son would receive quality services there because his son was a U.S. citizen” (Chuang 116). Many parents felt, “sometimes they told me to do one thing or another, and I refused because it wasn’t beneficial for my child” (Boyer et al. 173).

### **Goals and Aspirations**

Many immigrant parents immigrated to the United States for their children to have a prosperous future. When faced with the diagnosis of their child being intellectually or developmentally disabled, the future parents had envisioned for their child is compromised as parents, “realized that their children with disabilities might perhaps fall short of the promises they held out for those children as descendants of immigrants who had been expected to become success makers in this country (Gregoire 121). Some parents struggled to find professionals to educate their child and felt “a day without stimulation is a day lost” (Boyer et al. 173). Parents of children with disabilities expressed uncertainty about their child’s future, as the parents knew they could not always be there for their child (Byrne 53; Cheatham & Zeng 210). Some parents wanted their child to be independent and a part of working society with “competitive employment in a job that was not specifically created for a person with a disability, rather than ‘simulated work for token wages’” (Cheatham & Zeng 211).

### **Struggles and Improvements in Developing Countries**

Cultural perceptions and lack of social and medical support heavily affect the lives of people with intellectual disabilities, especially in developing countries (Xiong et al. as cited by Jiang, et al. 1182). In Guatemala, infant survival rates have been rising which means more children with disabilities due to birth difficulties are surviving (Replogle 1757), indicating a greater need for better disability programs. Cohen indicated many children with intellectual disabilities in Central and South America faced being institutionalized because of lack of support provided by the government (Frey & Temple, cited by Cohen 72). With the presence of intellectual and developmental disability awareness in the United States, families with individuals with disabilities will not have full accessibility to services if service providers do not take into account the underlying cultural factors that affect the perceptions of caregivers of individuals with disabilities. Replogle explains that even in developed areas of a country and in many rich countries, they still lack effective and caring public programs that provide good medical care (Wong et al., Tang & Li cited by Byrne et al. 54; Replogle 1758).

While children with intellectual disabilities (ID) in Central and South America are institutionalized because people with ID lack disability supports completely, in China, general education and special education were separated into different schools where intellectually and developmentally disabled children were not given proper education and instead “Teachers in the special school did not major in special education or even education. They are just like babysitters who look after the children and play with them,” (Byrne, Chiu, Yang, 52). Chuang et al. found first-generation Chinese-American parents with an intellectually disabled child who were, “in the

process of fighting for their son's kindergarten placement in a classroom for children with communication handicaps rather than accepting the school's recommendation for placement in a classroom for students with autism" (116). The discomfort of separating their children from neurotypical children may be from the perception that the special placement would function similarly to special schools in China, lacking attention to intellectually disabled children's needs. The school's refusal to recognize the wishes expressed by the parents exhibits the school's failure to acknowledge the parents' cultural perceptions. In China, parents of children with intellectual disabilities felt they could not rely on special schools to effectively care for their child (Byrne, et al. 52) which led to the establishment of non-governmental organizations with parents saying, "[their child] with autism who had no other educational alternative" (Deng & McCabe 1025). Non-governmental organizations have been made to fill the gap in special education that the Chinese government has left due to lack of supports (Deng & McCabe 1026). Hosek & Spaulding indicated "In order to determine the special education practices that work in Asian cultures, it is necessary to understand the influence that culture has on views of special education." (34), which establishes the need for the consideration of cultural factors in implementing special education practices for disabled children of immigrant parents. When immigrant parents immigrate to the United States, they carry over the culture they held in their home country, identifying the need for disability service providers to fully understand how culture impacts these parents' perceptions of disability care.

### **Gap Within Research**

There are over three million children with a disability (Young & Crankshaw) and over 44.9 million immigrants in the United States (Batalova et al.). Immigrant families have children with an intellectual or developmental disability but there has been limited research on immigrant parents' perspective on disability care in the United States compared to disability care in their home country, including cultural factors that tainted their experience with disability care in America. As advocates for their disabled child, parents' involvement in the disability care process is crucial to the prosperous future of their child. The divergent beliefs that exist between service providers and parents, especially prevalent in immigrant families, causes parents to be less involved in their child's disability care. Partnered with language barriers and service providers' cultural misconceptions, it is increasingly difficult for parents to fulfill their roles in the disability care process (Betrisey et al. 1231). The need for disability care providers to understand the cultural perceptions present in a parent's culture is then exacerbated due to other barriers that make it difficult for families to access disability care, even if resources are present. Due to the inadequacy of the government in many countries to provide kind and caring resources for children with intellectual and developmental disabilities, how an immigrant parent's ethnic culture intertwines with the dominant American culture needs to be considered in how parents navigate disability care for their child.

## Method

### Participants

Through convenience sampling, five parents who had immigrated to the United States were selected to participate in the study. All parents resided in different areas of South Florida and had a child with an intellectual and/or developmental disability (IDD). Given the specific population, no restrictions were made on which country the parents immigrated to the United States from or which IDD the child had, although all participants had children with autism, as seen in Table 1.

<i>Caregiver</i>	<i>Country of Origin</i>	<i>Relation to Child</i>	<i>Child's Age</i>	<i>Child's Disability</i>	<i>Interview Language</i>
A	Puerto Rico	Mother	21	Autism	English
B	Brazil	Mother	19	Genetic Mutation STXBP1, Autism	English
C	Colombia	Mother	14	Autism, Intellectual disability	English
D	China	Mother	17	Autism	Mandarin Chinese
E	China	Father	17	Autism	Mandarin Chinese

Table 1: Participant Demographic Information

All the participants' children were born in the United States. One participant was identified through a neighborhood app connecting people living in the Miami area, called NextDoor, in which the researcher posted a text post stating the objectives of the research project, that the participants would stay anonymous, that participants would be interviewed with a sample of the interview questions, the personal information that would be revealed about the participant and their child, and a link of a demographic questionnaire that included a section for the participant's preferred form of contact. Four participants were identified through students at a Miami public high school in which the researcher knew the student had a sibling with an IDD and gave these students the link to the demographic questionnaire, which also stated the objectives of the research project and the information that would be revealed in the research project.

### Interviews

Parents met the criteria of immigrant parents of children with intellectual and developmental disabilities (IDD) and were given informed consent forms with the objectives and goals of the research project, a sample of the interview questions, estimated time the interview would take, and a description of the information that would be shown in the research pertaining to their country of origin, child's age, and child's IDD. The child's age would allow the

researcher to take into account the amount of time the parent has attempted to and/or received disability services. The child's IDD would allow the researcher to see if there were differences in experience with receiving treatment because of the different intellectual and developmental disabilities the parents' children have. The participants' country of origin would allow the researcher to acknowledge different cultural factors in their experiences and observations. The researcher decided to concentrate research on immigrant parents because the primary gap within previous literature was the lack of consideration of how cultural perceptions would affect the way parents view and navigate disability for their children with IDD as immigrants in the United States. All participants remained anonymous and could choose to opt out of answering questions or restrict the information revealed in the research paper.

Prior to interviews, participants completed a demographic questionnaire regarding their country of origin, child's disability, and contact information and the informed consent form. The researcher met with participants through Zoom for interviews. The interviews were documented in voice recordings. The voice recordings were first transcribed with Otter.ai for interviews in English, and then the researcher checked the accuracy of the transcripts, editing as needed, and interviews in Mandarin Chinese were manually transcribed and translated by the researcher to English. When follow-up questions arose rereading the transcripts, the researcher contacted participants through their preferred form of contact for further questioning.

### **Data Collection**

The researcher chose a qualitative research design with a semi-structured interview format including similar open-ended questions to allow participants to thoroughly answer questions beyond the confines of quantitative research, providing opportunities for participants to elaborate as needed, giving the researcher a greater understanding of how different factors (ie. culture, race, stigma) intertwine in the experiences of the participants. The interview questions were meant to analyze the similarities and differences of participants' observations and experiences of treatment of people with IDD and disability care in their country of origin compared to the United States, considering cultural stigmas and perceptions; Questions also recognized feelings of hope or fear in participants for their child with IDD because they live in the United States.

The following is a sample of the interview questions:

- How have your views on disability changed since your child was diagnosed with (IDD)?
- Can you describe a time when you've felt disability professionals were inadequate in meeting the needs of your child in the United States?
- Can you describe instances in which you've felt it was difficult to access disability care (ie. no language interpreters, unavailable professionals, unaffordable, job interference, etc.) in the United States?
- Can you describe any experiences where you felt confident about disability professionals' ability to assist you and your child in the United States?



## Data Analysis

The researcher utilized coding to analyze data, first carefully rereading the interview transcripts and making note of similarities, differences, and surprising aspects of the participants' responses. Using open coding, quotes from the transcripts that had similar annotations were then grouped into categories. The categories were then formed into axial codes and then, higher-level axial codes, where themes emerged. The use of coding and allowing themes to emerge limited bias when analyzing the data because the data was guiding the formation of conclusions instead of the preconceived notions of the researcher, which could have resulted in attempting to prove or disprove a hypothesis instead of objectively looking at the data collected.

## Findings

Three themes emerged. The first theme, inclusion/mainstreaming, expressed the participants' child's proximity to neurotypical people, the stigma surrounding disability, and support. The second theme, inadequate services, describes the inadequacy of disability service providers, socioeconomic factors, cultural insensitivity, and lack of translators when attempting to access adequate disability care. The third theme, advocacy, detailed parents' advocacy for their child and factors that decreased or couldn't allow advocacy for the participant's child.

### Theme 1: Inclusion/Mainstreaming

#### *Stigma with Strangers*

3 out of 5 parents described moments in which their child was perceived as neurotypical but when people noticed some traits of neurodivergence, the people separated themselves from the child with Parent A explaining:

she's extremely white in her complexion. And people tend to gravitate to her because of it. She has blonde hair, they tend to gravitate towards her. But the moment they realize that she has a disability, they move away and that really hurts her, you can see that she realizes something is wrong.

Parent B described how she never experienced anything negative with her child except for one instance:

if you look at his face, you can't tell he has a disability. But if you see him walking, you can right away see that there's something wrong... When we were at the shoe store, this old couple entered the store. And when my child was walking, I was making him walk to see if the shoes were a good fit or not. They looked at him with like, a face of disgust.

#### *Family*

2 out of 5 participants described stigma within their family, with Parent A expressing:

Her father's side of the family teases her all the time. They laughed at her. That really hurts me because to do that to your own relative to me, that's just really low.

Although Parent B didn't express feeling stigma from extended family, she described discomfort from family because they didn't know how to interact with her child:



...him being nonverbal puts people in a place that they really don't know what to do. "If he doesn't talk, how am I going to communicate with him?" ...that would be I think the most common reaction that people show is like not knowing what to do, and not doing anything because they don't know what to do.

2 out of 5 parents expressed how their extended family did not treat their disabled child any differently than their neurotypical children, with Parent D expressing:

They treat him like a normal kid, they treat him very well. They know he doesn't speak very well so they try to teach him new words.

### *Lack of Understanding*

All parents had limited knowledge of the specifics of disability, with only two parents knowing friends who had family members with a disability or had interacted with disabled people before they immigrated to the United States and explaining there was only one specialized school for disabled people in their country of origin. Parent E explains:

In China, they had no specialized school or community for disabilities. I heard about people with disabilities, but I never saw them in my city... my child was the first person with a disability in my entire family.

Similarly, when asked about how her views on disability changed since her child was diagnosed, Parent B responded:

I don't think it changed, it just started to exist. Because my whole life, I was never around people with disabilities. In my family, my sisters, nephews, cousins, there was no one with disabilities. When I got married, my husband's family, same thing. So having my child with disability was like opening the door to something that we had no idea what it was, and how it would change our lives forever.

2 parents expressed cultural beliefs of their children growing out of their disability from extended family but later realizing the disability would be permanent.

### *Support*

3 out of 5 participants found support through their family, with Parent B describing:

My husband helps me a lot... My brother and sister-in-law, my niece, like when we travel, if we travel all together, my child needs full supervision, full attention for everything and everybody's like "oh, let's take turns, I do this, you do that, I can help you with that so you can take a break," So I feel very supported.

Parent A felt no support from her extended family but was able to find support from her church, in which her child was able to be a part of activities with neurotypical children, saying:

... she was a part of the dance group, mind you, she cannot dance, she has no rhythm, nothing. But the teacher really worked hard with her, and she was able to participate in every dance. Whatever the church had, and the group dance, she was able to participate and actually looked just like the others.

## **Theme 2: Inadequate Services**

### *Socioeconomic and Financial Factors*

3 out of 5 parents expressed their job interfered with accessing disability care, with Parent A describing how she couldn't attend all her child's IEP meetings and Parent D and E describing how they worked every day so they couldn't be as involved in their child's education. Parent B described how there was only so much care her family could afford because of her insurance:

...it's been a struggle to provide him with all the therapies he needs... because he needs therapies, nonstop to be able to walk he was in physical therapy, to be able to properly use the utensils, like there's so many things he can't do and if he is not in therapy, he loses the skills that he has learned. So, it was always a constant battle to try to get more therapy for him and not paying out of pocket because there's so much we can't afford.

Parent C described how services are very expensive in the United States compared to her home country, but currently, her family could afford the services.

#### *Inadequacy in Disability Service Providers*

All parents described moments when they've experienced inadequate disability care from professionals. Parent C stated:

I had a pediatrician from my country and maybe he wasn't so informed as he supposed. So, he'd say "no, you know what boys are normally a little bit delayed and girls are relaxed." And yes, my child was diagnosed kind of late.

3 parents had encountered service providers who lacked the patience to give their child proper care, with Parent D describing:

When he was 5 years old, my child got a really good and patient teacher, and he was really well behaved. But the agency changed to a mean teacher who lacked patience and my child started to hit people and he was very violent. I think the agency noticed the change in my child's behavior because they switched back teachers and he went back to being well behaved.

Parent C expressed, since disability care was still very new when her child was diagnosed, her child did try many different therapy approaches to find what worked for them.

#### *School*

The two parents who were not proficient in English described lack of communication with the school about their disabled child. Parent E had experience with disability care in Philadelphia and said it was significantly better compared to Florida's disability care because of the presence of translators and frequent communication between the parent and the school. Parent D described how she believed her child was treated well in school but was not sure:

School gives a lot of help, [my child] is more well behaved, but I don't know what really happens in school. They don't update me. They do help but they don't help a lot.

Parent A described how the only resources she was offered and aware of when her child was in school was the IEP program and recalled a special education teacher undermining her impact on her child's growth:

...the year when my daughter was to leave elementary school, the teacher told me that, "yes, your daughter has matured. But I don't think it has anything to do with you, because you're just an immigrant. It is because of the resources we provided her," and I was very humiliated.

Parent A also described the same teacher didn't allow her child to attend a special needs summer school, expressing:

...I wanted to send her to a summer school for disabled children and her special needs teacher from the elementary school, told me "No, no, she doesn't need it," whatever. But I still to this day believe that she would have been a better person or would be handling the world better now, had she'd been put with people who treated her, not necessarily that she was disabled, but taught her at her level.

Comparably, Parent C described how she saw many disabled students not being able to reach their full potential because of disparities in the school system:

... together they are in this like soup, where many of these kids have a lot of potential but because there is no resources and no people trained to deal with differences. They stay behind and I know this, many super smart kids are left behind because they don't have the right approach within the school system... that's the first problem with my child that sometimes his behaviors get in front of his potential, he's super smart but any little behavior, just disconnect him and people already say or assume that he doesn't know nothing.

Parent B also described the lack of resources in the school system, such as being short-staffed, caused her child to be cornered and unable to communicate that they needed to use the restroom because the teacher took away their child's device for communication.

### **Theme 3: Advocacy**

#### *Changing Therapists*

Out of the 3 parents who could communicate effectively with professionals in English, only 2 parents were able to receive adequate care while their child was in school. Both Parent B and Parent C described being hesitant to change therapists when they started seeking out different treatments for their child, as to not hurt the therapist's feelings or attempted to empathize with the therapist. However, Parent B realized that she needed to advocate for her child because he is nonverbal:

I learned from my child's very young age that I had to be on top of things and really look out for him if he can't talk, he can't say what he thinks, so I have to try and see what really works best for him.

Likewise, Parent C said:

I say, "No way, this is her job and everybody gets fired from their jobs if they don't do their jobs." So, I changed it very respectfully, of course, but I moved to another person that was right for him.

#### *Adequate Services*

Parent C recalled having to constantly advocate for her child and try out different treatments to find what would work for her child, but it allowed for her child to receive the services they needed:

I know it is difficult here too because we fight against a lot of issues here, but compare to the few that we receive here, it is a lot compared to what he will get [in Colombia]. So, I know we have to fight for every service he gets here, but he's getting services. So that's my priority and I see him happy. So, anything that he's receiving is working.

In the same way, Parent B expressed:

There are people that really believed in him, and were determined to push him a step forward, even if it's a tiny step. That's what we were always looking for. And it was very, very hard to find... everything he does, when I see videos, they send me from school, like he knows more than even myself would give him credit for. He knows, like basic things that I never expected him to be able to learn, like the word eat or drink.

Parent A was able to receive adequate services after her child was out of high school, through a school that her child volunteered at. The director of the school informed Parent A about a vocational rehabilitation center that the school system did not tell her about.

#### *Lack of Translators*

Due to Florida's lack of Chinese translators, Parent E expressed they felt they could not advocate for their child's services:

I think they have a serious problem with their system, but because of my language barrier, I have no way to change anything... It is hard to get things done. For the last 2-3 weeks, I've been attending IEP meetings, but the school system does not have an interpreter present at the meeting, only a translator on the radio.

Parent E later expressed regrets about not moving back to China when they immigrated to the United States because of their inability to advocate for their child:

If I knew the system was like this, I would have brought my children back to China to have my parents take care of my children. I didn't have a career in the United States yet, so I could've gone back to China. But my other child got sick in China, and I didn't want to risk the danger.

#### **Discussion**

Due to the lack of disability awareness in the parents' country of origin, the parents being faced with the diagnosis of their child with a disability in a completely new country is opening immigrant parents to a system that they have no understanding of how to navigate, which leaves the responsibility up to disability service providers to guide parents. Contrary to a previous study done by Deng et al., parents showed no indication of lack of social support (disability stigma or lack of understanding of disability from family) interfering with how they interacted with the

disability care system (2022, p.2919). However, unfamiliarity with treatments allowed for parents to try out many different treatments to find what would work for their child, as seen in Figure 1.

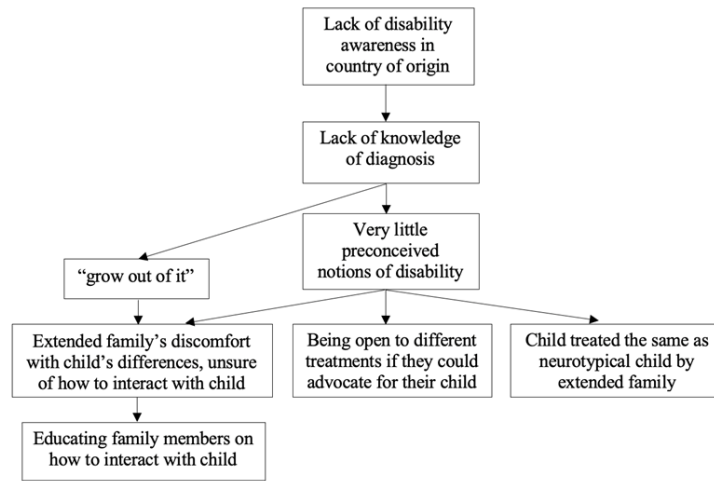


Fig. 1: Organization of Data (Inclusion/Mainstreaming)

The parents that received adequate care for their child did indicate their extended family believed their child's disability would be something they would grow out of, which may have encouraged the seeking out of the right treatments for their child.

The two parents who were able to receive adequate disability services for their child while their child was in school, Parent B and Parent C, were both proficient in English and immigrated to the United States because their family member or husband was offered a job in the United States, which indicates underlying socioeconomic factors that impact a parent's access to disability care, as Parent A, Parent D, and Parent E all indicated their jobs interfere with their ability to access adequate disability care for their child, as seen in Figure 2.

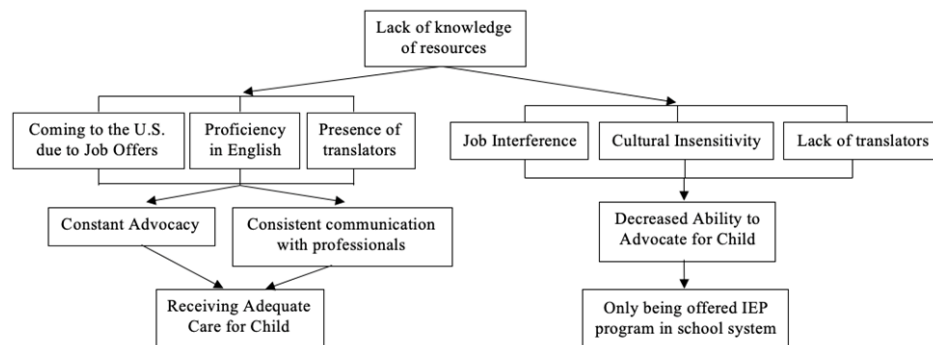


Fig. 2: Intersection of Inadequate Services and Advocacy

Although Parent B and Parent C did receive adequate care, they both emphasized they had to constantly advocate for their child and how difficult it was to find the right services. Parent E described the presence of Chinese translators in other states allowed their child to

receive adequate disability care but due to the lack of Chinese translators in Florida, decreased communication between the parent and the school, resulting in the parent being unable to advocate for their child to receive better care, which is acknowledged in a study done by Chuang et al., in which families could “actively participated in educational decision-making meetings by communicating through translators or other advocates, such as attorneys,” (119). Of the 3 parents who didn’t receive adequate disability care while their child was in school, Parent A experienced a teacher taking credit for all the parent’s child’s progress because the parent was an immigrant, which is consistent with a previous study done by Boyer et al. (174), in which parents are rarely attributed to the success of their disabled children, although it does not take into account the cultural stigma present in the experience. The presence of cultural stigma in the teacher also indicates the teacher may have purposely not informed the parent of the disability resources available in the United States which caused the parent to only discover vocational rehabilitation after their child had graduated from high school through a person who saw the parent as capable of helping their child. Parent B and Parent C had their children try many different therapies, whereas Parent A, Parent D, and Parent E had only had experience with the IEP program, which indicates the disparities within the school system require parents to seek treatments outside of the school system to receive adequate disability care, despite cultural insensitivity, lack of translators, and lack of awareness of the resources available, all playing a role in why these parents’ children have only received care from the IEP program. The parents who were not able to access adequate disability care while their child was in school corresponds to Lo’s finding that “Parents who feel respected and are considered as equal partners are more likely to continue to participate throughout their child's academic career. Because culturally and linguistically diverse parents may not have the skills or the knowledge to take on the roles that are expected by federal regulations and schools, professionals become the ones who can provide this population with guidance throughout the entire process,” (19).

### **Implications**

Immigrant parents need to be able to constantly advocate for the best care for their disabled child. If the parents need language interpreters in the presence of none, it leaves the parents unable to communicate with disability professionals, causing the goals of the parent to not be considered in the decision-making process for their child’s education. Disability service professionals also need to be informed of culturally sensitive language to make immigrant parents feel comfortable about communicating with the professionals, therefore, allowing for the parents to genuinely express their feelings about the care their child is receiving. The responsibility falls on disability service professionals to accommodate immigrant parents’ needs and be more culturally sensitive to allow for immigrant parents to advocate for their children, since professionals will not know the goals of the parent, which may lead to their child receiving insufficient care.

## **Limitations**

Two interviews were transcribed and translated from Mandarin Chinese to English by the researcher. With only one person translating the transcripts, there may have been bias during the translation process that the researcher was not aware of. All participants' children were born in the United States which prevented the participants from answering some questions that the researcher originally planned to ask in the interviews because it pertained to the parents' experience of disability care in their home country. No interviews were conducted in Spanish or Creole because the researcher did not have any people who could not efficiently communicate with professionals in English and communicated with professionals in Spanish or Creole reach out to be a part of the study, so the data does not represent the population of immigrant parents with disabled children in Florida. The researcher also utilized convenience sampling, so the data is not generalizable.

## **Conclusion**

Financial factors, language barriers, and cultural insensitivity were the primary factors in participants' struggle to find adequate disability care. Parents needed to constantly advocate for their child to get the services their child needed, and when parents couldn't advocate due to job interference, cultural insensitivity, and lack of translators, parents were not informed of the resources available and could not receive adequate care for their child. Boyer et al. explained "some parents feel like they are being left to their own devices and find themselves 'in limbo.' They are worried that their child is a 'victim' of this wait time because the child is not receiving all necessary support services during this period," (173). Immigrant parents are left to fight for the proper services for their child without the guidance of disability service professionals while they are in a brand-new country in which they need to consistently communicate with disability service professionals to get proper services, even though the professionals may not be able to provide accommodations to allow for the parents to advocate for their child.

## Works Cited

- Almasian, Mohammad, Malekshahi, Farideh, & Rezaian, Jafar. "Intellectually Disabled Children and Their Parents' Problems: Preliminary Evaluation and the Suggestion of Effective Strategies." *Crescent Journal of Medical and Biological Sciences*, vol. 7, no. 3, 2020, pp. 336–341.
- Batalova, Jeanne, Hanna, Mary, & Levesque, Christopher. "Frequently Requested Statistics on Immigrants and Immigration in the United States." *Migration Policy Institute*. Last modified February 11, 2021. Accessed April 30, 2023.  
<https://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states-2020>.
- Boyer, Thierry, Leblanc, Line, & Robert, Marie. "When Satisfaction Is Not Directly Related to the Support Services Received: Understanding Parents' Varied Experiences with Specialised Services for Children with Developmental Disabilities." *British Journal of Learning Disabilities*, vol. 43, no. 3, 2015, pp. 168-177.
- Byrne, Victoria, Chiu, Marcus Y. L., Yang, Xue. "Caregiving Experience for Children with Intellectual Disabilities among Parents in a Developing Area in China." *Journal of Applied Research in Intellectual Disabilities*, vol. 29, no. 1, 2016, pp. 46–57.
- Cheatham, Gregory A. & Zeng, Songtian. "Chinese-American Parents' Perspectives about Using the Internet to Access Information for Children with Special Needs." *British Journal of Special Education*, vol. 44, no. 3, 2017, pp. 273-291.
- Chuang, Shu-Ju L., Huer, Mary Blake, Parette, Phil. "First-Generation Chinese American Families' Attitudes Regarding Disabilities and Educational Interventions." *Autism and Other Developmental Disabilities*, vol. 19, no. 2, 2004, pp. 114-123.
- Cohen, Shana R. "Advocacy for the "Abandonados": Harnessing Cultural Beliefs for Latino Families and Their Children With Intellectual Disabilities." *Journal of Policy and Practice in Intellectual Disabilities*, vol. 10, no. 1, 2013, pp. 71–78.
- Dababnah, Sarah & Kim, Irang. "Appreciation of the 'Subtle Changes': Perspectives of Korean American Parents Raising Children with Developmental Disabilities." *Journal of Developmental and Physical Disabilities*, vol. 32, 2020, pp. 307–322.
- Deng, Meng, Hou, Yujia, Yan, Tingrui. "Direct, Indirect, and Buffering Effect of Social Support on Parental Involvement Among Chinese Parents of Children with Autism Spectrum Disorders." *Journal of Autism and Developmental Disorders*, vol. 52, no. 7, 2022, pp. 2911–2923.
- Gregoire, Josee. "An Analysis of Haitian Parents' Perceptions of Their Children With Disabilities." *ProQuest ETD Collection for FIU*, AAI3470219, 2010.  
<https://digitalcommons.fiu.edu/dissertations/AAI3470219>
- Hosek, Melissa & Spaulding, Lucinda. "Special Education in China: Exploring the Perceptions of Chinese Teachers." *Journal of Ethnographic & Qualitative Research*, vol. 15, no. 1, 2020, pp. 34-46.



- Jiang, Fan, Lei, Hao, Lu, Ming-Hui, Shi, Meng-Liang, Wang, Guang-Hai, Zhu, Rui. "Social Support as Mediator and Moderator of the Relationship Between Parenting Stress and Life Satisfaction Among the Chinese Parents of Children with ASD." *Journal of Autism and Developmental Disorders*, vol. 48, no. 4, 2018, pp. 1181–1188.
- Lo, Lusa. "Demystifying the IEP Process for Diverse Parents of Children with Disabilities." *Teaching Exceptional Children*, vol. 44, no. 3, 2012, pp. 14-20.
- Rosen, Sandra & Zhang, Yuexin. "Confucian Philosophy and Contemporary Chinese Societal Attitudes toward People with Disabilities and Inclusive Education." *Educational Philosophy and Theory*, vol 50, no. 12, 2018, pp. 1113-1123.
- Young, Natalie A.E. & Crankshaw, Katrina. "Disability Rates Highest Among American Indian and Alaska Native Children and Children Living in Poverty." *United States Census Bureau*. Last modified March 25, 2021. Accessed April 30, 2023.  
<https://www.census.gov/library/stories/2021/03/united-states-childhood-disability-rate-up-in-2019-from-2008.html>.

## **An Argument for Classical Music: The Evolution and Appreciation of a Genre By Cliff Yuen**

Classical music. Ranging from the grandeur of the Bach church masses or Beethoven symphonies, to the modest and humble Mozart sonatas, this genre encompasses everything that music has become. It has helped shape and influence generations of composers, such as John Williams and Hans Zimmer, to compose iconic film soundtracks we know and love in the 21st century, from *Jurassic Park* to *Star Wars*. But classical music is not what it used to be. Although the genre is making a comeback now, it has still not been brought back to equivalent popularity as it was before. So, before we dive into the cesspool and open the violin case that is classical music, we will try to understand why it is not where it used to be, albeit with a lot of improvement.

### **Movement 1: Elitism**

Contributing to the exceptional trials and tribulations that classical music has to face in today's society is the existence of stereotypes and assumptions, with elitism being one of the most prominent. This, in many ways, is inaccurate because music often relates and resonates with wider audiences, drawing people in with its emotional depth and power. However, many individuals interested in expanding their musical worldview are pushed away due to perceived elitism in the classical community. People who are less interested in classical music often regard regular classical music listeners and concert-goers as snobbish and impolite, which discourages those looking to expand their musical worldview. Consequently, this perception of elitism contributes to the often limited conversation of classical music in modern and contemporary discussions. Having established a brief view of elitism in today's society, it is also important to consider sources that have experienced elitism in a professional orchestral and musical environment.

According to the YouTube musical duo TwoSetViolin, there is so much more to classical music in a professional environment. From their experience, TwoSetViolin has said that pop musicians do not want to play with them because they think they are better than classical musicians. They play the music because it has become their passion over time and they love playing it. I can relate to this quite well, as I, too, have developed a love for orchestral music. As a student in the top string ensemble in my school, we often play movements of symphonies with the top band in our school. Now, whenever I get ready for a concert, I come alive; I know my peers and I are about to bring a piece to life, whether it be an orchestral suite, a concerto, or a symphony. From Eddy Chen's perspective, one of the two members of TwoSet, there is an incorrect portrayal of how people are actually like in the classical music industry. This is also true from my end; when I remember my first time playing in an orchestra, I did not know what I was doing. But the upperclassmen of seniors and juniors were not condescending at all and were very helpful in guiding me through this new experience. Although this is from my own

experience, there are other reasons why elitism plays a big part in classical music's modest standing in today's society, such as its rules and etiquette.

### **Movement 2: Rules and Etiquette**

When it comes to an orchestral concert, rules and etiquette are a fickle thing. But let me boil it down to the basics. When it comes to the rules of attending an orchestral concert, the most prominent rule, or one of, is that the commonly accepted attire is at least a semi formal outfit, such as a Polo shirt with khakis. I remember one instance when I went to see the Chicago Symphony Orchestra play; I went with a stormtrooper shirt and was shooed away by the usher until he saw that I had tickets, at which point he let me in. Now, I wonder if it was my stormtrooper t-shirt that finalized the usher's decision or if it was that I was 11 at the time with friends who were also the same age. Hence, audience members are expected to have at least a semi formal look when attending a concert. When classical music was even more ostracized from the general community in the early 2000s, people would often criticize these concerts for their rules, such as the dress code. But these codes are there because it is a part of the culture of classical music, as French Fries are a part of the culture of McDonald's. As fries have been recognized as McDonald's staple snack, it is important to note that it was the same traditions that kept it alive; if the traditions for classical concerts are broken, it will not be a classical concert anymore. As former orchestral violist Viola Geena said, "These etiquette rules' existence is not elitist; it's what is widely accepted by the culture" and "people who frequently attend these concerts have high expectations for audience etiquette and zero tolerance for texting during the performance or clapping between movements." This is true to some extent, as during the pause between movements, musicians often "rely on the silence between movements to mentally prepare for what comes next" (Geena).

Going back to dress codes, the contrast for an orchestral concert and a pop concert are mismatched, even polarizing at times. For example, at a pop concert you can wear almost anything, but at a classical concert, you have to wear something semi formal and cannot applaud the performers until after the performance. But, during the pop concert, you can applaud the performers and be as loud as you want.

Reasons like these make classical music a bit separated from the general society, and I wish that classical music were to modernize more and cater to the masses. Unfortunately, all the famous composers of the Classical and Romantic eras have passed on, hence why the western classical canon such as Beethoven, Bach, and Mozart cannot evolve as modern music does. But, recently, major orchestras around the world such as the Chicago Symphony Orchestra and the Singapore Symphony Orchestra have been adapting to the masses and are slowly modernizing.

### **Movement 3: The Modern Day**

Now, during the modern era, concert attendance and revenue are more often based on popularity and fame. Although some orchestras like the Berlin Philharmonic and Chicago Symphony Orchestra have a lot of history behind them and are some of the most respected

orchestras in the world, they still pale in comparison to stars such as Justin Bieber, Beyonce, Jay-Z, and Ed Sheeran; the inclination towards fame and popularity nowadays has been more favorable towards stars in the pop music industry. With the introduction of streaming platforms and social media sites such as Instagram, Spotify, and SoundCloud, stars such as Justin Bieber and Ed Sheeran have been able to reach a variety of wider audiences, helping them achieve extraordinary heights and unparalleled achievements, such as platinum plaques for the most platform streams in a year. This has made it more difficult for orchestras around the world to compete, as they simply do not have the same appeal for funding and for marketing based on stardom alone; tickets for a Taylor Swift concert would reach a lot more people than tickets for a

### **Berlin Philharmonic concert.**

However, orchestras around the world still have devoted listeners that will go to their concerts regularly, and classical music as a whole is still an important staple and a predominant practice in today's society. But, in some ways, the shift towards stardom and fame has caused soloists and major orchestras around the world to embrace social media to connect with fans and potential newcomers. One great example of this is Ray Chen, a Taiwanese-Australian violinist, who has over 300k followers on Instagram alone. He often posts about his practice sessions and recent concerts, but he also does comedic videos to connect with his current fans and potential newcomers who see his videos. Another great example is the Chicago Symphony Orchestra. They host a series of family concerts throughout their regular orchestral season, inviting children to experience an orchestral concert for the first time. Its most popular program is "Once Upon a Symphony," with the main shows being presented in Symphony Center's intimate Buntrock Hall, not the main orchestra hall, as the main orchestra hall is usually reserved for more formal concerts with stricter dress codes. "Once Upon a Symphony" weaves chamber music performed by members of the Chicago Symphony Orchestra with storytelling, sets, costumes, and multimedia to create a captivating and magical introduction to live music for children ages 3-5 (*Chicago Symphony Orchestra*). They tell a story of fairy tales through music, and often after the concerts, the kids are allowed to go up to the musicians, talk to them, and see their instruments up close.

Despite the efforts that orchestras make to adapt to the changing world, there is still a great financial toll compared to more popular genres. One of these distinctions is the cost of tickets for said concerts, as concerts with worldwide celebrities such as The Weeknd can cost hundreds and even thousands of dollars. A notable example is when ABC News found that classical music tickets are cheaper on average than contemporary music; in 2017, the average classical concert ticket cost was \$77.12, while a pop gig would cost \$105.73. While yes, orchestral concerts would usually be more expensive if you are going for a front row view, a concert featuring the Berlin Philharmonic would be more financially accessible than a concert featuring Justin Bieber. Going back to an earlier argument, people often pay more for DJ concerts or football games, as they are more widely accepted. I feel like pianist and writer Chris Lloyd put it perfectly: "Football is also expensive to attend, ditto pop gigs and festivals, but no

one suggests that these activities are ‘elitist.’” With the amount of customs and traditions that first-timers have to follow when going to a concert, it is understandable why people would rather go to football games; there are less traditions, and it is generally more relaxed.

Ultimately, there are still speckles of elitism in classical music today, but it is important to realize that even with the surrounding stereotypes, it can still be enjoyed and admired by people of all ages. For a more 21st century vibe, people can look to artists such as Laufey collaborating with the Iceland Symphony Orchestra. If one wants a more contemporary film vibe, people can look elsewhere towards film scores, with Hans Zimmer and *Interstellar*, John Williams and *Star Wars*, Howard Shore and *The Lord of the Rings*, or Alan Silvestri and *The Avengers*. Ultimately, classical music continues to push boundaries and offer timeless renditions of the old ways that carry us to universes of joy and excitement.

### **Finale: Conclusion**

Although one may feel uncomfortable when going to an orchestral concert, one would argue that it would actually benefit your musical worldview as a person. You see, it is not just violins, violas, cellos, etc. It is an artform that wills us to appreciate the alluring harmonies and immeasurable creativity that flows from the orchestra, and it lets one experience not just the composer's music, but their thoughts and emotions as well. I vaguely recall my first time going to an orchestral concert. The HK Phil were playing Brahms' 4th Symphony, and I remember going into the concert hall thinking I could sleep through the entire thing. But I left a new person, awed by what I had seen. It made me contemplate what I had just heard, like I had ascended into another plane of existence and widened my view of music as a whole, opening my eyes to the likes of symphonic masses' grandeur, the flair of operas, the modest sonatas, and the humble but majestic piano trios. The reason it is so different from music nowadays is that the pieces have been perfected multiple times; it was one composer with his own skill that composed it, not a team of people with machinery and autotune, which really makes one appreciate symphonies and concertos more.

So, if you have finished reading this paper and gained a new interest in classical music, I would like to give you a few of my favorite recordings:

1. Shostakovich Symphony No. 5: A piece that brings out the harsher side of classical music. My personal favorite is the recording that Leonard Bernstein does with the New York Phil.

2. Mahler Symphony No. 9: Mahler's farewell to the world, signifying the death of the world that Mahler knew. My personal favorite recording is again Leonard Bernstein with the Vienna Philharmonic.

3. Mahler Symphony No. 4: One of Mahler's lesser known symphonies, presenting a child's view in heaven. A personal favorite recording of it is Claudio Abbado with the Lucerne Festival Orchestra.

If these recordings are not suited for you, I would recommend listening to film music, as it has been heavily influenced by classical music. Take Harry Potter's soundtrack for example, as

it is extremely influenced by the styles of Beethoven and Mozart. Indeed, these composers distinctively incorporate elements reminiscent of the great masters like Beethoven, Mozart, and Bach, using orchestras to create sweeping melodies and intricate harmonies that evoke the same sense of greatness found in the old works of the classical masters.

In addition to the heavy spiritual moments that seem to transport one to another world, there are also playful and joyful pieces that capture the wonder of the magical world. From the modest “Hedwig’s Theme” to the sweeping “Voldemort’s Theme,” it not only enhances the modern cinematic experience, but it pays homage to the musical traditions that have inspired generations of film composers. Much like the magical world it goes hand in hand with, this soundtrack is a masterpiece that transports audiences to a land of enchantment and joy, yet still shows the enduring influence of classical music on film.

As we strive to restore classical music to a place of equivalent popularity like it was back in Mozart’s or Beethoven’s time, we can look towards film music to find points of similarity in the massively popular soundtracks we hear today and the building blocks of western classical music that continue to bring film to life. As more and more people immerse themselves into film music, it can nurture an appreciation for what classical music inherently is: an intricate and enduring artform. Similar to how film scores bring tears to our eyes and goosebumps in the climactic moments, classical compositions are able to resonate with our souls and speak to our emotions, similar to scoring the winner in the World Cup Final for your country or getting accepted into your dream school. I wrote this paper to encourage you to listen to classical music, and if not, film music. As with both genres, we have the opportunity to bridge the gaps, restore the allure of classical music, and bring it back to the forefront of society today.

## Works Cited

- Chenoweth, Jonathan N. "An Outsider's Guide to Classical Music: Teaching the Western Canon as 'Other.'" *College Music Symposium*, The College Music Society, 1 Oct. 2009, [symposium.music.org/index.php/49/item/9120-an-outsider-s-guide-to-classical-music-teaching-the-western-canon-as-other](https://symposium.music.org/index.php/49/item/9120-an-outsider-s-guide-to-classical-music-teaching-the-western-canon-as-other). Accessed 19 June 2023.
- Geena, Viola. "Is Classical Music Elitist?" *The Riff*, 4 Apr. 2021, [medium.com/the-riff/is-classical-music-elitist-3320f9d24c56](https://medium.com/the-riff/is-classical-music-elitist-3320f9d24c56).
- JDCuebas. "Lights, Camera, Symphony: How Music Shaped Films." *Fort Collins Symphony*, 17 Mar. 2023, [fcsymphony.org/blog/history-of-film-music/](https://fcsymphony.org/blog/history-of-film-music/).
- Noyes, Hope. "The 'Classic' Excuse: Why Classical Music Isn't Boring – Hawk Herald." *www.hawkherald.com*, 22 Jan. 2022, [www.hawkherald.com/2022/01/the-classic-excuse-why-classical-music-isnt-boring/](https://www.hawkherald.com/2022/01/the-classic-excuse-why-classical-music-isnt-boring/).
- "Our Opinion on Elitism in Classical Music." *www.youtube.com*, TwoSetViolin, [www.youtube.com/watch?v=ldBlc1HHCGA&pp=ygUUdHdvc2V0dmlvbGluIGVsaXRpc20%3D](https://www.youtube.com/watch?v=ldBlc1HHCGA&pp=ygUUdHdvc2V0dmlvbGluIGVsaXRpc20%3D). Accessed 18 June 2023.
- "Once Upon a Symphony: The Elves and the Shoemaker | Chicago Symphony Orchestra." *Chicago Symphony Orchestra*, 1 Apr. 2023, [cso.org/performances/22-23/cso-for-kids/once-upon-a-symphony-the-elves-and-the-shoemaker/](https://cso.org/performances/22-23/cso-for-kids/once-upon-a-symphony-the-elves-and-the-shoemaker/). Accessed 16 Oct. 2023.
- Pianist, The Cross-Eyed. "Who Made Classical Music 'Elitist?'" *The Cross-Eyed Pianist*, 24 July 2019, [crosseyedpianist.com/2019/07/24/who-made-classical-music-elitist/#:~:text=So%20there%20is%20a%20curious](https://crosseyedpianist.com/2019/07/24/who-made-classical-music-elitist/#:~:text=So%20there%20is%20a%20curious).
- "The Relationship Between Classical Music and Pop Music." *MustHaveClassicalMusic.com*, 27 July 2018, [musthaveclassicalmusic.com/classical-and-pop-music-relationship/](https://musthaveclassicalmusic.com/classical-and-pop-music-relationship/).
- "Why Is Classical Music Considered Elitist?" *Interlude*, 20 July 2019, [interlude.hk/classical-music-elitist-might/](https://interlude.hk/classical-music-elitist-might/).

# An Overview of Neonicotinoid Environmental Concerns and Impact on Non-Target Species

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## Abstract

Neonicotinoids are a class of economically important insecticides, becoming the most-widely used insecticide class in the 21st century. They act mainly as antagonists to nicotinic acetylcholine receptors (nAChRs) through irreversible binding, inducing tetanus and finally, paralysis. In comparison to traditionally used organochlorines, organophosphates, and carbamates, neonicotinoids are a more efficient and cost-friendly choice. However, their direct and indirect threats posed to the surrounding environments of applications and non-target species have come under scrutiny. Presented here is an overview of existing research on neonicotinoid water contamination, impact on soil microbial communities, and degradation patterns, as well as their effects on non-target aquatic species. The linkage of neonicotinoid presence and Colony Collapse Disorder (CCD) in honey bee species is further described, and the pathways of exposure, acute toxicity, and physiological effects on humans is detailed. This paper aims to provide a culmination of existing studies in describing and detailing the concerns associated with increased neonicotinoid usage as their application continues to expand.

## Introduction to Insecticides & Neonicotinoids

The exponential increase in the global population over the last century is largely attributed to major advances in the agricultural industry<sup>1</sup>; the decades leading up to and following the green revolution of the 1980s saw the expansion of industrial farming practices, chemical fertilizers, processed foods, and high-yielding variety seeds, increasing crop output and the valuation of the agricultural industry. As of 2023, the global market for agriculture is valued at ~13.3 trillion USD, and that number is projected to grow to ~19 trillion USD by the year 2050. Given the sector's economic



importance as a leading source of revenue generation in many countries, maintaining crop output has been at the forefront of agricultural innovation. Notably, a major task has been to better control insect (e.g. aphids, mites, beetles, thrips, flies, and other bugs) feeding, which is one of the leading causes of crop output loss. Typically, insect feeding coincides with their reproductive cycles and morphological development, and many insects limit stem, stalk, and root growth in plants by continued feeding, thereby reducing the chance of plants surviving to maturity and fruit production. Additionally, grubs and other burrowing insects interfere with mycorrhizae (root-fungi interactions), which reduce the uptake of vital ions and inorganic minerals from the soil. It is estimated that around 30 - 36% of all crops produced around the world are lost to routine feeding by insects<sup>2</sup>. To sustain yields, the usage of chemical insecticides - synthetically produced compounds used to kill target specific insects - has been increasing since the 1940s. Insecticides are divided into two main categories: contact (or foliar) and systemic. Contact insecticides are applied non-specifically on the periderm, waxy cuticle, or other external surfaces of plants, where they can come in direct contact with target insects. In contrast, water-soluble systemic insecticides are applied at specific locations of host plants, where they are uptaken and distributed throughout the plant via vascular tissue. The majority of insecticides used today (including organophosphorus compounds, organochlorines, carbamates, pyrethroids, and diamides) are of the contact type, although many newer classes of insecticides are systemic in nature. The application of both categories depends on the intrinsic chemical properties of the insecticide, the target insects, and regulations on usage.

Approximately 9 million metric tons of insecticides are used annually and their application is expected to continue to increase beyond the year 2050<sup>3</sup>. Further, insecticides represent 60% of all pesticide use, with approximately 6000 individual insecticides in usage<sup>4</sup>. Although traditional insecticides such as organophosphates and carbamates have been extensively important throughout agricultural history and continue to be used in many developing agrarian economies, there has been extensive lobbying for modern alternatives, citing environmental concerns, danger to mammals, and overuse.

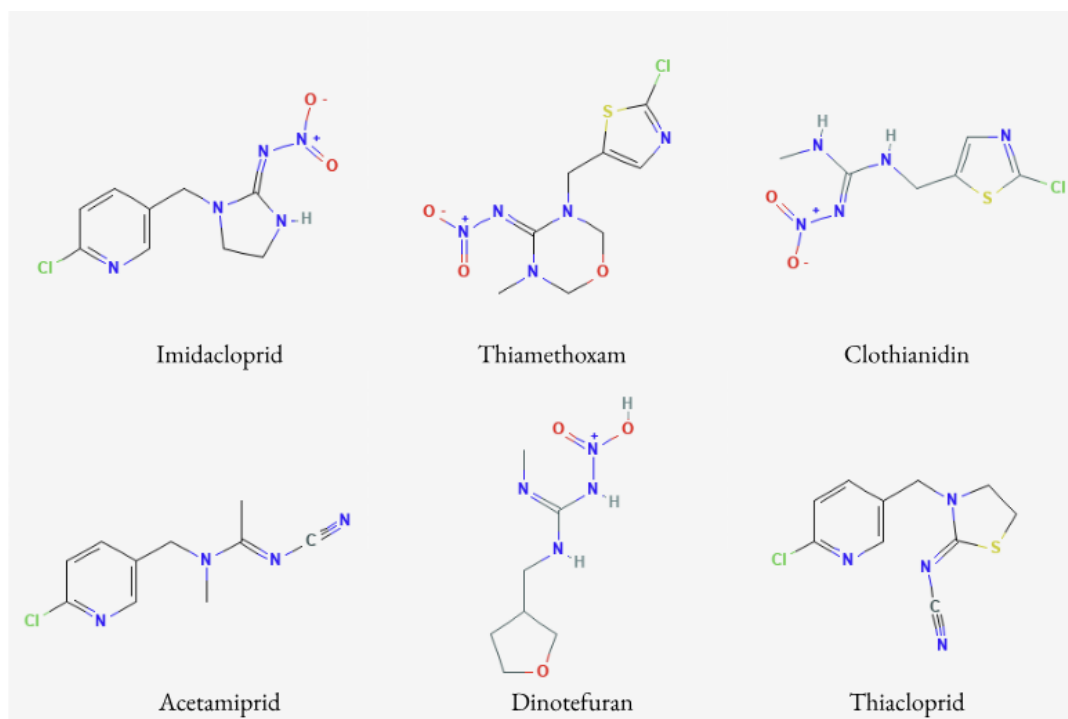
Neonicotinoids, or neonics, are synthesized derivatives of nicotine with insecticidal properties. They irreversibly bind to nicotinic acetylcholine receptors (nAChRs) in insect ganglion cells, eventually resulting in full-body paralysis<sup>5</sup>. Neonics are more easily synthesized than many other insecticide classes, and have furthermore been noted to possess an increased target range. These factors have made them a rising force in the global insecticide market, and they now possess a 25% share of the global insecticide market, with over 3000 neonicotinoid products available globally<sup>6,7</sup>. The first commercialized neonicotinoid, imidacloprid, was released in the early 1990s and was heavily used in seed coatings and foliar sprays because of its systemic protection against aphids and mites. Since then, neonics have been an integral part of agricultural pest protection against a host of insects, and have additionally seen menial uses in urban settings as well, present in many insect sprays and poisons. Some

of the highlights of neonicotinoid usage include their relative stability against aquatic and photocatalytic (light) degradation, as well as their ability to travel effectively to all parts of host crops<sup>8</sup>. Although these properties allow for a higher chance of absorption by target insects, they can also lead to environmental accumulation. Residues of neonicotinoids have already been found in food products, surface water, wastewater, and groundwater<sup>9,10</sup>. While neonicotinoids pose less acute toxicity than many other types of insecticides, the environmental and chronic health hazards they pose have not been fully researched, and remains an active area of study<sup>11</sup>. Furthermore, neonicotinoids have been linked to colony collapse disorder (CCD) in the honeybee species *Apis florea* and *Apis mellifera ligustica* (as well as other bee genera)<sup>12</sup>. The connection between neonicotinoids and CCD is discussed further later in this article. Given their extensive uses in agriculture, economic benefits in comparison with other insecticide classes, and environment/health hazards, understanding how neonicotinoids operate and interact with host and target organisms is a necessity. This article will review neonicotinoid development, cellular actions, agricultural uses, and environmental and health hazards.

## History & Development

For much of the 19th century, nicotine (in the form of nicotine sulfate) was burned near economic crops to protect against aphids and other bugs. While the effectiveness of this method demonstrated nicotine's insecticidal properties, the chemical was also toxic to mammals, which resulted in the end of its use around 1940. Instead, research shifted to chemically-similar molecules that were less toxic to non-target species in comparison with nicotine. The first precursor to modern-day neonicotinoids, nithiazine, was first synthesized in the 1970s when it was discovered that a class of heterocyclic compounds containing a nitromethylene functional group (C-NO<sub>2</sub>) could act potently on nAChRs<sup>13</sup>. It was additionally found that this compound was more effective than a variety of then-up-to-date insecticides against the housefly (*Musca domestica*) and other fly species, including the widely-used hexachlorocyclohexane (HCH) and its derivative, lindane. The discovery, which came from Henry Feuer, hinted at the possibility of a wider range of nicotinic derivatives with insecticidal properties. More than a decade later, Schroeder and Flattum confirmed that nithiazine acted as an acetylcholine receptor antagonist that competes with acetylcholine (ACh) for active binding spaces on nAChRs<sup>14</sup>. This was a major breakthrough in insecticidal development, as nithiazine was not an acetylcholinesterase inhibitor (which prevented the breakdown of acetylcholine by acetylcholinesterase) like most insecticides at the time. Following further testing and the addition of an imidazolidine ring [(CH<sub>2</sub>)<sub>2</sub>(NH<sub>2</sub>)<sub>2</sub>(CH<sub>2</sub>)] to the existing nithiazine structure, the first commercially-ready (and eventually most economically important) neonicotinoid was created: Imidacloprid<sup>15</sup>. The compound was first sold under brand names such as Admire<sup>®</sup>, Advantage<sup>®</sup>, and Merit<sup>®</sup>, although the

number of imidacloprid products available in the market has since grown greatly. Further changes to the base nithiazine structure in the late 1990s led to the release of a variety of neonicotinoid products, infamously thiamethoxam in 1998 and clothianidin in 2001. Imidacloprid, thiamethoxam, and clothianidin were all patented by Bayer AG, a leading figure in the neonicotinoid market that has since patented many more neonic products. Figure 1 depicts the chemical structures of six of the most commonly used neonicotinoids. The first neonicotinoid mixture (developed in 2005) was a foliar spray consisting of various carbamates and the neonic acetamiprid; the spray was widely popular in the United States, where it was used to protect soy and wheat plants from aphids<sup>16</sup>. Since then, neonicotinoids have been heavily utilized for their protection against root-dwelling insects, as well as their specificity against a larger host of insect targets. Additionally, they have been of great economic value to insecticide companies, as neonics are far more profitable in terms of their cost of production-valuation ratio in comparison with organochlorine and organophosphorus-based compounds. Given their popularity, neonicotinoids represent one of the fastest growing sectors of insecticidal research and usage. The development of neonicotinoids from the base nicotine/nithiazine molecules to the current selection of neonics is notably also a reflection of scientific advances; the use of X-ray crystallography patterns, mass spectrometry, and inorganic chemical synthesis, as well as new understanding of neural receptors and their interactions have played a crucial part in advancing neonicotinoids through the past few decades.

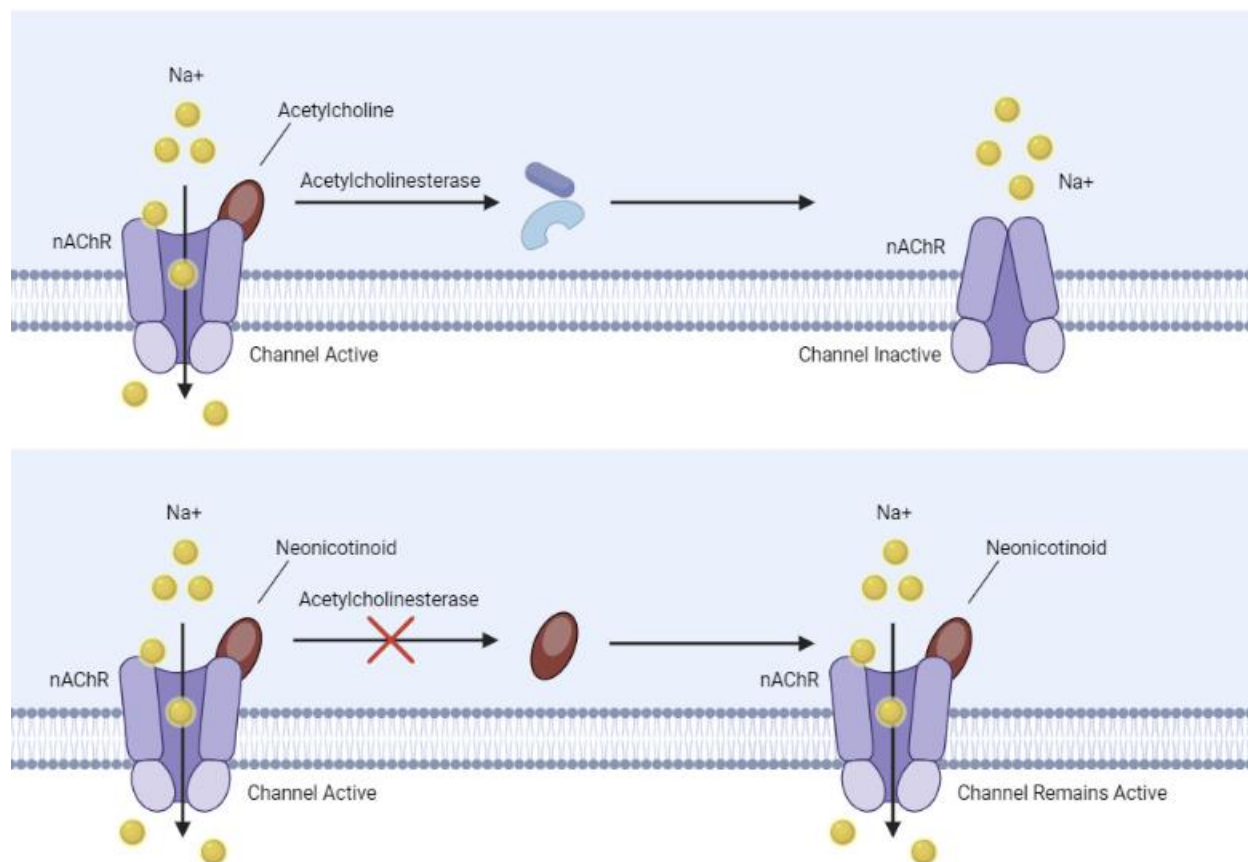


**Figure 1: Chemical structures of the six most commonly used insecticides globally.**

## Structure & Mode of Action

Neonicotinoids, which have similar chemical properties to the chemical nicotine, are aromatic heterocyclic compounds that can be divided into two main groups: N-cyano amidines and nitroguanidines. The prior consists of a  $R-C\equiv N$  cyanoamidine functional group attached to a nitrogen atom on the central neonicotinoid structure<sup>17</sup>. Examples of N-cyano amidines include the neonics acetamiprid and thiacloprid. Nitroguanidines, on the other hand, are neonics with a nitro ( $R-NO_2$ ) functional group bonded to a central nitrogen atom. Imidacloprid, thiamethoxam, and clothianidin are all examples of nitroguanidine neonics. Nitroguanidine compounds are less reactive with mammalian and non-target receptors, which is why they are more common in agricultural settings<sup>18</sup>. A key feature of neonics is the presence of an elastic bond between the defining functional group and the base heterocyclic structure. All neonics are water-soluble and electronegative in charge, which allows them to be taken up by the root via ion-gated channels selectively permeable to hydrophilic substances. Neonics are then transposed to all vascular and nonvascular segments of the plant - from the fruit to the leaf. Thus, a major advantage of systemic neonicotinoids is their ability to protect the whole plant, unlike contact insecticides, which rely on direct interactions with insects. The insecticides themselves pose little damage to the host crops, however, the effects that neonicotinoids have on ion balances within plant cells is an ongoing area of research<sup>19</sup>.

Once ingested by target insect species, neonicotinoids work to disrupt neural activities by targeting receptors at postsynaptic junctions on neural pathways. Specifically, these insecticides interfere with the activity of the nicotinic acetylcholine receptor (nAChR). *Reversible* binding of neurotransmitter acetylcholine (ACh) to a nAChR causes swift depolarization of the cell membrane, thereby communicating a neural signal<sup>20</sup>. To reestablish ionic balance and repolarize the membrane, acetylcholine is hydrolyzed into acetic acid and choline by the enzyme acetylcholinesterase (AChE). Following a neonicotinoid binding to a nAChR, a typical action potential is registered and appropriate cell mechanisms take place. However, neonics bind *irreversibly* to nAChRs, meaning that AChE is unable to perform hydrolysis and action potentials are sustained throughout the refractory period<sup>21</sup>. On a larger scale, this leads to tetanus and, eventually, full-body paralysis of the target insect. Figure 2 describes the binding of neonicotinoids to nAChRs in comparison with the biomolecule ACh. Thus, neonics are competitive inhibitors that disrupt homeostatic behavior in neural and neuromuscular regions.



**Figure 2: Reversible binding of acetylcholine to an acetylcholine receptor (top) in comparison with irreversible binding of a neonicotinoid (bottom).**

Neonicotinoids are effective against most insects because the insect brain possesses a high density of nAChRs, increasing the probability of successful binding to a receptor. Insect nAChRs are made up of three  $\alpha$ -subunits (loops A-C) and three non- $\alpha$ -subunits (loops D-F) that make up the allosteric binding site for ACh and neonics<sup>22</sup>. While it is still being studied, a potential reason for neonicotinoids' heightened target specificity in comparison to older insecticide classes is the varying spatial configurations of nAChRs between insects and non-target species classes. In mammals, there are many types of nAChRs with varying loop counts and thus varying structures, so the likelihood of neonic binding is low<sup>23</sup>. Specifically, neonicotinoids have been proven to be most effective against the  $\alpha 4\beta 2$  receptor (made up of  $\alpha 4$  and  $\beta 2$  subunits), which comprises almost all of insects' nAChRs, but only ~10% of human and other mammalian nAChRs. The other ~90% is made up of other nAChR variations to which neonicotinoids have low to moderate substrate binding properties<sup>24</sup>. Homomeric (singular type of subunit) examples of such other nAChRs in mammals include the  $\alpha 7$  and  $\alpha 9$  receptors, while heteromeric (two or more unique subunits present) examples include the  $\alpha 3\beta 4$  and  $\alpha\beta\epsilon(\gamma)\delta$  receptors. Regardless of this variation, mild toxicity has been noted in non-target species; the

effects of neonics on humans are discussed in detail later in this article. In addition, neonicotinoids in partially or fully degraded forms can interact with enzymatic reactions in a wider variety of species, including microbial communities, thus expanding the potential range of species affected (though effects are depressed).

The precise dosage of neonicotinoids is critical and is influenced by a variety of factors including the type of neonic used, the insect species, the target insect's morphological stage, and the arrangement of the protein nAChRs in the central nervous system. As such, the dose requirements of the same neonicotinoid might vary based on the target insect. Furthermore, the general toxicity of related neonicotinoid insecticides in comparison with one another must be considered. To compare the relative acute toxicity of related neonics (or any class of insecticides), it is standard practice to use a model insect, such as the housefly (*Musca domestica*) or the Japanese beetle (*Popillia japonica*). Table 1 depicts the dosage of varying neonics required to kill 50% [LD<sub>50</sub>] of the common true bug *Apolygus lucorum*, as per a study by Pan & Lu [2014]<sup>25</sup>. There are various guidelines regarding neonicotinoid applications from prominent sources of authority such as the EPA, EU, and the Australian PVMA. Slight deviations in recommended application quantities likely stem from different tolerances of runoff and neonic presence in water/food sources.

**Table 1: LD<sub>50</sub> ranges for different neonicotinoids on *Apolygus lucorum* (adapted from Pan & Lu).**

<b>Neonicotinoid</b>	<b>Median LD<sub>50</sub> (ng/adult <i>P. japonica</i>)</b>
Imidacloprid	8.94
Nitenpyram	5.68
Acetamiprid	8.69
Thiamethoxam	17.39
Dinotefuran	10.79
Thiacloprid	12.32
Clothianidin	14.95

# Environmental Risks of Neonicotinoids

While neonicotinoids present economic advantages compared to other organic and inorganic insecticides classes, they come with a set of defined concerns. Specifically, their effect on non-target species (including microbial communities) is a point of note. There has been considerable research into the negative physiological effects [sublethal or lethal] on different species with acute or prolonged exposure to neonicotinoids. As so, a discussion of neonic effects on surface water - home to many affected aquatic species - is presented. Additionally, the dangers posed by neonicotinoid contamination of aquifers and soil is stated, while a brief mention is made on the bioaccumulation and degradation patterns of the insecticides. Given the continued usage of neonicotinoids under the assumption of being a 'safer' alternative to organophosphorus compounds, organochlorines, carbamates, and other insecticide classes, a discussion on the comprehensive risk of using neonics on the ecosystem is necessary.

## Surface Water Contamination

A major environmental concern of neonicotinoid application is the threat it poses to surface water; the presence and effect of this insecticide in freshwater sources near agricultural settings is an area of active research. Neonicotinoids can enter surface water through various routes, although primary accumulation has been noted through surface runoff in the water<sup>10</sup>. A study by Berens et al. [2021] found that only 1% of neonicotinoids applied through foliar sprays and 3% of neonicotinoids applied in seed coating are actively uptaken during ion exchange. The limited sorption of neonicotinoids is modeled through a linear isotherm, with varying sorption coefficients,  $K_C$ . The observed sorption coefficients of thiamethoxam, imidacloprid, and clothianidin were ordered in  $K_C$  (Thi. > Imid.  $\approx$  Clot.) In various observed tests,  $K_C$  of neonicotinoids ranged from 1.5 - 5 gL<sup>-1</sup> ( $p < 0.05$ ), indicating slow, positive uptake of neonicotinoids into plant taproot<sup>26</sup>. It should be noted that many of the related studies in this area were performed in controlled settings, which differ greatly from environmental conditions found in nature. Specifically, precipitation and resulting surface runoff are examples of dynamic properties of water [and dissolved solutes] movement. Neonicotinoids, when applied in the soil, tend to accumulate in specific hydrophilic regions from where they are uptaken through ion exchange. Such regions are typically found in topsoil - a layer susceptible to movement of solutes and water<sup>27</sup>. Thus, precipitation and excessive water concentrations can lead to surface runoff, where these neonicotinoids are transported to larger water sources, including lakes, rivers, streams, backwaters, marshes, and ponds.

Further, neonics can also enter surface water through other forms. In urban settings, dissolved neonicotinoids can pass into freshwater through wastewater treatment plants (WWTPs) water

expulsion<sup>28</sup>. This is more common in developing nations with limited filtration infrastructure. Neonic presence in watersheds additionally factor into their ability to travel from smaller, contained bodies of water to larger, uncontained regions. Leaching from groundwater sources into surface water through simple diffusion is furthermore observed in certain hyporheic zones, where chemical exchange occurs with the surrounding surfaces. Neonicotinoids can also enter the atmosphere through the process of adsorption, where they attach to larger pollutant molecules, mainly frass, the solid excreta of insects and other species<sup>29</sup>. Here, concentration gradient-driven gas exchange at the air-water interface facilitates the diffusion of neonicotinoids into the water source. While these different actions impact the ability for neonicotinoids to enter surface water, <40 ng - 100 µgL<sup>-1</sup> have been noted in certain trials, indicating both the limited effect on neonic presence as a dissolved solute in comparison to surface runoff and direct accumulation, where over 500 µgL<sup>-1</sup> have been noted in samples.

Neonicotinoids in a dissolved state have lower toxicity towards aquatic life in comparison with foliar and systematic applications on economic crops<sup>30</sup>. However, acute toxicity of imidacloprid, thiamethoxam, and clothianidin, amongst other neonic derivatives, have been observed on both vertebrate and invertebrate species. In the former, the insecticides act directly upon nAChRs in the central nervous system while in the latter, they act upon analog receptors in circular nerve nets or organized ganglia. Spectrophotometric assays performed by Butcherine et al. [2021] found sublethal effects on the juvenile Black Tiger Shrimp (*Penaeus monodon*) that included reduced enzymatic activity of acetylcholinesterase, catalase, and glutathione S-transferase in abdominal tissue<sup>31</sup>. Additionally, limited spasmodic movement was noted in neonicotinoid-exposed experimental units in this and other studies when compared to controls, which corresponds to the over-propagation of action potentials in select muscle cells when exposed to neonicotinoids. Acute toxicity (LD<sub>50</sub> following ~2 days) was determined as 1 µgL<sup>-1</sup> in clothianidin, <400 µgL<sup>-1</sup> in thiamethoxam, and >408 µgL<sup>-1</sup> in imidacloprid. A long-term static renewal study on the effect of neonics on the freshwater invertebrate *Hyalomma azteca* further found that mobility was affected at insecticidal concentrations nearly 60 times lower than the LD<sub>50</sub><sup>32</sup>. Reduced survival rates were also noted acutely in post-larval shrimp following exposure to imidacloprid and a close analog, fipronil when placed in environmentally challenging conditions. Indicated here are the major sublethal effects of neonicotinoids in non-target species, as well as the complex effect of bioaccumulation in aquatic species. The cherry shrimp *Neocaridina denticulata* had reduced locomotive activity and gill ventilation, similarly to the effect on other shrimp species of the same genus<sup>33</sup>. In the small freshwater Chinese minnow (*Rhyncocypris oxycephalus*), when neonicotinoids were present in 0.1 - 2.5 ppm, oxidative stress increased, while the production of immunoglobulin M was downregulated by reduced signaling transmission<sup>34</sup>. The complex effects described as a result were reduced immune functioning and protection against pathogens. While these and other similar studies indicate definable sublethal (and in some cases, lethal) effects of dissolved neonicotinoids at LD<sub>50</sub> or similar concentrations, the typical concentration of dissolved



neonicotinoids in surface water samples is far lower than that of the selected experiments<sup>35</sup>. However, the results of various studies suggest that even when found in trace quantities (defined here as <5 ppm), there are observable effects on aquatic creatures, and even if not lethal or sublethal, speaks to the importance of limiting the entry of neonicotinoids into surface water.

## Effect on Groundwater

Similar to surface water, groundwater (stored in porous aquifers) is prone to neonicotinoid leaching; such contamination carries serious public safety hazards given the dependence on groundwater as a source of drinking water in many parts of Asia, Africa, and South America<sup>36</sup>. The general structure of a groundwater system consists of a discharge (surface-air interface), unconfined aquifer, confining bed, and a confined aquifer. Most drilling activities rely on the presence of drinking water in the confined aquifer region. It was previously assumed that the water in this region was pure, and thus, an informal filtration process was often the standard in areas dependent on groundwater<sup>37</sup>. However, weak rock-soil interfaces in agricultural settings allow for the leaching of water (and its dissolved contents) from the surface to the unconfined and the confined aquifer. Of the dissolved substances, neonicotinoids have been identified in many studies to be present in confined aquifers in an active, partially active, partially degraded, or fully degraded state, as measured by mass spectrophotometry and ion-exchange chromatography. Figure 3 provides an overview of the process of insecticide contamination of groundwater.

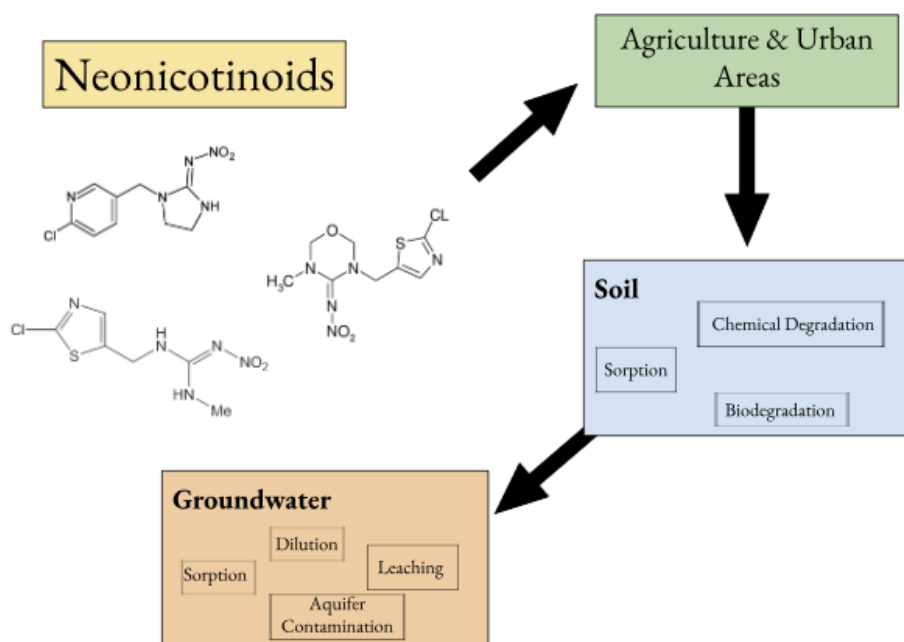


Figure 3: The process of transformation and contamination of neonicotinoids in groundwater aquifers.

Monitoring of hyporheic zones in riverbeds for the presence of neonicotinoids in an Iowa economic soy crop region found that the insecticides were present at 0.13 - 0.98 ppm. The rate of simple diffusion into unconfined aquifers occurred at ~14.4% per hour, which is partially due to the pressure exerted from the surface water above<sup>38</sup>. The Thompson et al. [2021] article found that rates of neonicotinoid absorption were directly proportional to both the quantity of neonicotinoids applied and the porous structure of the aquifers. A study on the prevalence of neonicotinoids [and sulfoxaflor] in alluvial (clay, silt, sand, etc.) aquifers identified the presence of imidacloprid, thiamethoxam, clothianidin, acetamiprid, dinotefuran, and thiacloprid. While only trace quantities of acetamiprid, dinotefuran, and thiacloprid were found, 73% of the studied aquifers contained statistically significant quantities of either imidacloprid, thiamethoxam, or clothianidin. It has been established that clothianidin is most susceptible to groundwater leaching, although the reasons for the increased rate of gradient-based diffusion remains unknown<sup>39</sup>. Quantitative ranges of different neonicotinoids' presence in confined aquifers have been established from various studies: 34 - 391.7 ngL<sup>-1</sup> (clothianidin), 6.7 - 42.4 ngL<sup>-1</sup> (imidacloprid), and 0.2 - 1.6 ngL<sup>-1</sup> (thiamethoxam).

A pilot study in midwestern United States - where neonicotinoids reign as the most popular insecticide - found that from 47 assessed groundwater samples, neonicotinoids were present in greater than 50%, with two or more present in greater than 10%. Clothianidin was the most frequently detected in the analyzed well water, present in 55% of all samples with a maximum concentration of 140.5 ngL<sup>-1</sup>. Imidacloprid and thiamethoxam were found at 13% and 6% of all samples, with maximum concentrations of 29.3 ngL<sup>-1</sup> and 13.1 ngL<sup>-1</sup>, respectively. In addition, the effects of contaminated groundwater contamination were demonstrated through chemical separation analysis of urine<sup>40</sup>; Human exposure could be seen in the presence of ~10 neonicotinoids or transformation products in urine samples; Clothianidin, imidacloprid, and thiamethoxam were found at ~4.7 µgL<sup>-1</sup>, 1.4 - 1.6 µgL<sup>-1</sup>, and 3.2 - 3.4 µgL<sup>-1</sup>, respectively. Most of the partially degraded transformation products were detected in trace quantities, although the presence of acetamiprid-N-desmethyl at 16.9 µgL<sup>-1</sup> in urine samples indicates either a potential degradation metabolic pathway or a degradation process prior to consumption<sup>41</sup>. The results of the pilot experiment represent the quantitative presence of functional neonicotinoids in groundwater (unconfined and confined), as well as their persistence following passing through the human metabolic system. This necessitates a serious consideration of groundwater filtration processes and their effectiveness in limiting the passage of neonicotinoids into drinking water. Additional research is required into the process by which neonics pass through from the surface into confined aquifers, in addition to the partial degradation patterns that occur when present in aquifers.

## Impact on Soil Microbial Communities

Neonics can remain in the soil for a prolonged time, as the systematic uptake through direct interactions with roots or via hyphae (fungal network) is a slow process<sup>42</sup>. While present in the soil, the insecticides are subject to leaching, biodegradation, and chemical transformation. Different chemical natures of varying soils (e.g. pH, temperature, density, water content, etc.) additionally influence the fate of the neonic.

Topsoil is generally a ground for rich microbial growth and diversity, given the abundance of organic matter as energy. However, it has been indicated that the presence of neonicotinoids in soil (in either a functional or semi-functional state) can possess acute adverse effects on the homeostasis regulation of microbes.

Neonicotinoid, cyclic urea, cyclic guanidine, nitroso, and other insecticide derivatives are degraded by certain eukaryotic and prokaryotic microbes; eukaryotic genera *Apiotrichum*, *Gamsia*, *Humicola*, *Kitasatospora*, *Solicoccozyma* and prokaryotic genera *Sphingomonas*, *Streptomyces* and *Terrabacter* possess catabolic pathways involved in the metabolism of heterocyclic, aromatic compounds such as neonicotinoids<sup>43</sup>. Specific biodegradation patterns are discussed in the following sections. In a controlled environmental setting, it was found that close to 45% of identifiable microbial communities experienced negative change in population growth in the presence of different neonicotinoids<sup>44</sup>. Labrie et al. [2020] further concluded that anywhere from 0 - 42% of Hay bacillus (*Bacillus subtilis*) showed reduced rates of cell division, protein output, and growth following exposure to thiamethoxam imidacloprid, and clothianidin ( $p < \sim 0.3$ )<sup>45</sup>; negative homeostatic changes observed were minimal, yet remained statistically significant. Soil microbial population change of *Ensifer adhaerens* was determined by assessing select spectrophotometer samples, revealing a negative change in the population size index of selected microbial populations<sup>46</sup>; quantitative analyses of diversity changes were limited due to the presence of external, uncontrolled chemical factors, including changes in pH and temperature. Both of the presented studies confirm a correlation between increased neonicotinoid presence and negative homeostatic changes, although direct causation was not established in either test. In the ammonia-oxidizing archaea community *Methylothera* and some nitrifying/nitrogen-fixing communities, the ability for organisms to successfully engage in nitrogen-cyclic metabolic pathways was limited when imidacloprid was applied at high concentrations<sup>47</sup>. The change in populations of these microbial communities ranged from 3 - 6.3%, and it is plausible that negative neonicotinoid interactions with the nitro-reducing enzyme nitroreductase was responsible for the inability for certain microbes to efficiently convert atmospheric  $N_2 \rightarrow NH_3$ . While these and other conformational studies indicate the toxicological effects of neonicotinoids on species without nervous systems or nerve nets, there have been many experiments which note no change in population size, density, or overall functioning of certain microbes when

exposed to neonicotinoids<sup>48</sup>. Thus, the effect of insecticidal exposure on select soil microbes is directly correlated to the soil conditions, species-specific toxicity variations, and degradation patterns of the neonics in both intracellular and extracellular settings.

There has been limited research regarding the specific interactions occurring between neonics and microbial enzymes that result in changes in cell functioning. However, certain pathways impacted by the presence of partial binding of select neonicotinoids have been noted through the use of X-ray crystallography and protein separation analysis. Dimeric avidins, biotic-binding proteins part of the microbial defense system against extracellular disease vectors, were underexpressed when neonicotinoids thiamethoxam and acetamiprid were present<sup>49</sup>; an unusually high presence of avidin in the form of an avidin-vitamin complex indicates reduced cell viability and/or proliferation. Additionally, it is presumed that the reduced production of dimeric avidins acts secondarily in limiting microbial populations by reducing protection against other harmful species and viruses. The enzyme responsible for oxidizing reduced pyridine nucleotides (NAD, NADP), hydroxyacid oxidoreductase, was found to be – unlike dimeric avidins - overexpressed in *Rhizobium* microorganisms in the presence of significant quantities of neonicotinoids (specifically, a heterocyclic derivative of imidacloprid)<sup>50</sup>. It is proposed that the balance between oxidized and reduced NAD and NADH in the cell is affected by the overexpression of hydroxyacid oxidoreductase, altering the ability for cells to undergo the citric acid cycle and oxidative phosphorylation efficiently. Additional studies are required to validate this hypothesis. Other studies have found that neonics and partially degraded derivatives can act as cationic aromatic substances (similar to the nucleotides themselves) capable of hydrogen bonding with the base reservoir of the DNA helix<sup>51</sup>. Through groove binding, thiacloprid and imidacloprid were observed to insert themselves through weak interactions in the DNA ladder itself. The resulting destabilization of the macromolecule results in a slight increase in the length of the DNA molecule and a slight decrease in thermal stability. While the understanding of the effects of such interactions are still limited, interactions with any functional macromolecule - specifically DNA, RNA, and proteins - can have strong implications for gene expression.

In addition, certain physiological processes have been identified to be either upregulated or downregulated by the intracellular presence of neonicotinoids although knowledge of the enzymes and substructures specifically affected have been limited. Biodegradation processes are made up of various enzymatic pathways, and it has been shown that prolonged, extensive exposure to certain neonicotinoids in soil microbes result in reduced *N*-deacetylation and oxidative cleavage<sup>52</sup>; the prior plays a key role in the folding process and stability of proteins, while the latter introduces different functionalities to complex molecules. One study concluded a weak correlation between the quantity of neonicotinoid and the level of suppressive methylations pertaining to certain deacetylation proteins in the roundworm species<sup>53</sup>. However, the overall understanding of the effect of neonics in soil

microbial communities remains limited, and a greater depth of research is required to understand the effects of their presence in prokaryotic and eukaryotic microbes' homeostasis.

## Degradation Patterns

In the environment, neonicotinoids are prone to degradation into smaller, organic or inorganic compounds. Metabolites resulting from degradation may be rendered ineffective in acting against insects, while some may still maintain insecticidal properties<sup>54</sup>. This subsection discusses the different processes by which neonics are degraded in the environment following their application and associated concerns.

Microorganisms of the genera *Apiotrichum*, *Gamsia*, *Humicola*, *Kitasatospora*, *Solicoccozyma*, *Sphingomonas*, *Streptomyces* and *Terrabacter* possess specific catabolic pathways for neonicotinoid degradation through enzyme-substrate catalysis. Acetamiprid breakdown analysis using chemical separation techniques (relying on known degradation patterns) found that nitrile hydratase was acted upon in *Ensifer meliloti* and *Streptomyces canus*<sup>55</sup>. Specifically, a transformation pattern of acetamiprid into the metabolites IM-1-2, IM-1-4, and IC-0 was noted in a linear degradation process. Additionally, a protein coded for by the *ahnA* gene in *E. meliloti* responsible for the transformation of acetamiprid to IM-2-1 was identified as being a factor in neonicotinoid degradation. The N-desmethyl metabolites IM-1-2 and IM-2-1 have been identified to possess limited acute toxicity to soil microbes and roundworm species, suggesting that microbial degradation may further reinforce negative effects of neonicotinoids in the environment.

Thus far, around 29 genes and 10 proteins have been identified in the partial or full degradation of imidacloprid in various microbes. CYP353D1v2, a cytochrome p450 enzyme/coenzyme, has been identified as a primary enzyme responsible for microbial biotransformation of neonicotinoids<sup>56</sup>. A substrate depletion test identified that when overexpressed, the cytochrome is responsible for the creation of an unknown heterocyclic compound that showed insecticidal properties corresponding to minor sublethal changes in behavior. Microbial degradation of neonicotinoids, seen through the insecticidal properties of degraded products, does not serve any purpose; rather, the insecticides possess similar structures to beneficial or useful heterocyclic compounds. YK-624, a catalyst-enzyme present in certain *Stenotrophomonas* microbes, has been shown to cleave a nitroguanidine functional group from the structure of clothianidin, resulting in the formation of methyl nitroguanidine and 2-chloro-5-methyl thiazole<sup>57</sup>. Both of these compounds were further degraded into either cationic or uncharged aliphatic substances. Of the degradation patterns observed through YK-624, certain products were eventually oxidized to carbon dioxide, while others possessed a limited association with a decrease in *Stenotrophomonas* populations (relationship needs further clarification). Other patterns identified include removal of amidine groups from imidacloprid,

thiamethoxam, clothianidin, and acetamiprid through the use of deaminase and N-deacetylase, resulting in varying metabolites with similar, less, or no insecticidal properties in comparison to the reactant insecticide, respectively.

While there is much to learn on the methods by which soil microbes can degrade anywhere up to 60% of neonicotinoids applied, a focus must be directed towards the impacts of the metabolites on other soil microbes, non-target organisms, and their presence in surface water and groundwater. There have been certain correlations drawn to a negative environmental effect, but additional studies are required to identify the enzymatic causes of the observed relationships.

Another form of neonicotinoid degradation is through photocatalytic means, which uses light energy to drive advanced oxidative catabolism. Specifically, absorption of photons at specific wavelengths causes electron excitation and oxidation of larger molecules, creating cleaved products. The excitation of electrons in neonicotinoids mainly occurs in hydroxyl radicals (-OH), and can result in the formation of weak acids, such as 6-chloronicotinic acid<sup>58</sup>. Degradation caused by the formation of carbonate and oxygen-based products is referred to as indirect photolysis, while degradation from sunlight is direct photolysis<sup>59</sup>. Neonicotinoids, like many other insecticides, are prone to breakdown from both direct and indirect photolysis. In experiments using photodegradation lamps, it was found that anywhere from 8-25% of the neonicotinoids present in a soiled surface were partially degraded over the course of 48 hours, with thiamethoxam being most susceptible to degradation, followed by clothianidin and imidacloprid<sup>60</sup>. In water, the half-life of neonicotinoids varies greatly, and typically depends on the pH, temperature, and molarity<sup>61</sup>. Direct photolysis has resulted in the degradation at a half-life range of 12 min (imidacloprid) - 42 hours (thiamethoxam), while indirect photolysis of imidacloprid results in a half-life range of 5 hours - 19 hours<sup>62</sup>. The varying half-life values depend on the quantity of photoenergy supplied. At a 270 nm light wavelength (indirect photolysis), thiamethoxam and imidacloprid were nearly 87% degraded, with other derivatives following at ~75 - 83%, indicating susceptibility of certain chemical components in their respective structures to excitation. However, there have been limited studies that emulate realistic environmental conditions, where the balance of direct and indirect photolysis is in constant flux<sup>63</sup>. Additionally, there has been little research on how the chemical products of photolysis affect aquatic and terrestrial life, although some studies describe the effect of agriculture on photolysis in surface water; many water bodies near agricultural settings are more sediment-impaired, meaning more light scattering (direct photolysis impaired), and thereby a longer degradation half-life<sup>62</sup>. This has been a factor in explaining the extensive presence of neonicotinoids in large water sources for long periods of time.

A major process by which neonicotinoids are degraded in the environment is hydrolysis in bulk water. In large samples of water, such as in lakes, rivers, and estuaries, neonicotinoids interact with different solutes and dissociated products; in a theoretical study involving dinotefuran found that at a C-1=N-2 bond, a proton transfer to N-2 (from interactions with hydroxyl) creates an unstable

product, prone to degradation<sup>64</sup>. Similarly, in alkaline water conditions, thiamethoxam was observed to react with minerals and water itself to form more stable guanidine compounds, such as aminoguanidine (or pimagedine)<sup>65</sup>. Concerningly, pimagedine (and certain other products from neonicotinoid hydrolysis) has antimicrobial and acute insecticidal properties<sup>66</sup>.

Hydrolysis of imidacloprid at a certain energy level can form 8-Hydroxydeoxyguanosine (8-OHdG), an oxidative reactant known to be a marker of DNA damage<sup>67</sup>. Certain second-level hydrolysis reactions may form more toxic - even carcinogenic - products, such as the formation of hydroxylamine and protonated nitrogen ions from a degraded thiamethoxam. Hydroxylamine has been linked to certain forms of bladder cancer if present in heightened levels in human urine<sup>68</sup>. Additional research is required to better understand the environmental risks posed to agricultural communities by neonic hydrolysis, as most studies regarding the matter are performed in controlled settings.

Neonicotinoids have also been noted to be subject to partial or complete degradation (into simpler heterocyclic or inorganic compounds) through exposure to hard metals, volatilization, or other abiotic transformations<sup>69,70</sup>. As far as biotic transformations go, it has become of increasing concern the effect of neonicotinoids in their degraded states on non-target insects and mammals, including a potential toxicity to humans. Studies on the degradation patterns *in vivo* have shown mild to severe effects on non-target species, encompassing sublethal and lethal effects, depending on the species<sup>71</sup>.

## Linkage to Colony Collapse Disorder

Honeybee colonies play a crucial role in shaping ecosystems by acting as pollen distributors. Bees contribute over \$30 billion USD to the global agricultural market and collectively make up one of the most economically important sets of insect species. Colonies are composed mainly of worker bees, drones, and a queen, and remain active typically throughout the winter season and while food supply is present; they are only abandoned if structural damage is present or the queen bee dies. Colony Collapse Disorder (CCD) is an abnormal phenomenon in honeybee species where worker and drone bees disappear, leaving their colonies, queen, and young alone<sup>72</sup>. Many beekeepers reported abnormal behaviors in bees arising from CCD-affected colonies, including reduced foraging ability, bees not returning to the colony, and disorientation<sup>73</sup>. The disorder was first described in Europe, 1998, where upward of 50% of certain western honeybee *Apis mellifera* colonies saw a sharp decrease in the number of male workers and drones in the wild<sup>12</sup>. In the United States, the winter seasons of 2006-2007 and 2007-2008 saw large-scale withdrawals of managed *A. mellifera* populations, resulting in upward of \$1 billion dollars in losses. A study of over 400,000 American managed colonies conducted

in 2008 found that 35.8% of all colonies reported partial or total losses of worker bees; of these colonies, nearly 60% did not identify dead bees present, a primary symptom of CCD<sup>74</sup>. There have been various theories identifying the main causes of CCD, including the ectoparasitic mite *Varroa destructor*, various endoparasites, airborne viruses (such as the chronic bee paralysis virus), and notably, chemical insecticides<sup>75</sup>. As such, studies have shown that the use of neonicotinoids, especially imidacloprid, have detrimental, sublethal effects on different pollinator bees which have been in turn linked to CCD.

Neonicotinoids are permitted to be applied at different times of the year depending on the crop in question, and are translocated to the pollen and nectar of the affected plants, explained by their systemic nature<sup>76</sup>. Thus, there is a direct potential for honey bees in proximity to agricultural settings to be exposed to neonicotinoids at various sites, as well as for the insecticide to be present in the nectar they collect. It should be noted, however, that given the reduced quantity at which neonicotinoids are applied compared to older insecticides, the exposure to bees is prolonged, rather than acute. Established pathways discussed here include majorly exposure through food, as well as interactions with contaminated plants, water, and spray drift (direct exposure). There is, however, significant variability in existing data regarding neonicotinoid exposure to bees, in part due to the large foraging range, variation in different colonies, and difficulty in identifying a singular cause to CCD<sup>77</sup>. Different honey bees with different roles in colonies are exposed to neonicotinoids in different ways; for instance, worker bees do not consume pollen or pollen grains, but instead bring it back to their colonies where other types of bees, such as nurse bees and immature young, do consume them<sup>78</sup>. Such variability further makes it difficult to triangulate a primary source of neonicotinoids in colonies suffering from CCD.

A study conducted in Europe (2006) found that nearly 70% of pollen collected from 125 samples contained either significant or trace quantities of imidacloprid, 6-chloronicotinic acid, and 35 other derivatives<sup>79</sup>. Here, imidacloprid was found at quantities ranging from 1.1 - 5.7  $\mu\text{gKg}^{-1}$ , 6-chloronicotinic acid at 0.6 - 9.3  $\mu\text{gKg}^{-1}$ , and a close derivative, fipronil, was found in 9 samples at elevated levels ( $>10\mu\text{gKg}^{-1}$ ). Another 3-year study identified the presence of imidacloprid and clothianidin in various plant nectars [ $\sim 41\%$  of tested samples] at concentration ranges of 0.3 - 5.4 micrograms per kilogram<sup>80</sup>. That same study found elevated levels of thiamethoxam on guttation drops of oilseed rape plants. Honeybees of *A. mellifera* were noted to interact with these guttation drops and trace quantities of applied thiamethoxam were found in various tested colonies. Imidacloprid and dinotefuran residues were furthermore found in over 98% pollen coating of tested pumpkin plant in a 2012 study; the study identified parent neonics from various detected metabolites, including desnitro olefin, urea, and 6-chloronicotinic acid<sup>81</sup>. In the common cantaloupe *Cucumis melo var. cantalupensis*, up to 4  $\text{mgL}^{-1}$  of imidacloprid was recorded on dew particles, with additional findings on the presence of imidacloprid and cyclic urea in beeswax produced by the same bees that

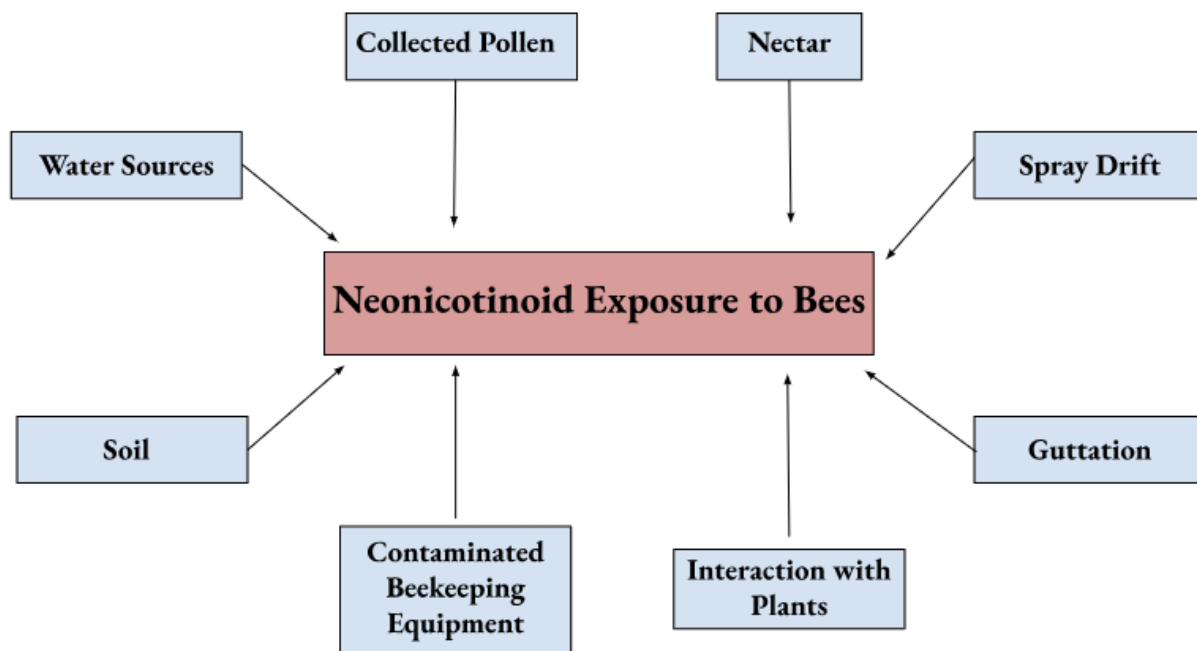


interacted with the dew<sup>82</sup>. The study completed by Girolami et al. [2009] not only identified a linkage to CCD in >50% of tested colonies, but furthermore noted that various drone and worker bees sampled died within minutes of exposure, indicating a lethal effect posed by exposure to the insecticide. In addition, Zhang et al. [2023] found that the increased bioavailability of imidacloprid in controlled soil settings corresponded with decreased foraging and desire for food - trademark signs for CCD<sup>83</sup>.

A leading critique of the idea that neonicotinoids have a direct impact on CCD has been that honey bees can identify sources with neonic coating present, be it in nectar, pollen, or guttation drops. However, it was discovered in 2015 that both *A. mellifera* and *Bombus terrestris* bees do not avoid nectar-relevant concentrations of imidacloprid, thiamethoxam, or clothianidin<sup>84</sup>. Rather, bees preferred sucrose solutions with both imidacloprid and thiamethoxam present over regular sucrose solutions. Neonicotinoids stimulations did not excite any sensory or sucrose-sensitive neurons at statistically significant levels compared to trials, indicating an inability in bees to recognize neonicotinoids in undegraded forms. Thus, neonics pose a major environmental risk by acting as a physiological detriment to bees while maintaining no sensory deviation from normal food. Nectar containing neonicotinoids is unknowingly passed to nurse bees and larvae as a result, where consumption of the toxic insecticides occurs. The presence of neonicotinoids [in concentrations greater than  $5\mu\text{gKg}^{-1}$ ] in pollen collected by drones has shown to create a significant decrease in nurse bee populations, along with reduced carbohydrate and lipid metabolism in larvae<sup>85</sup>.

Neonicotinoids possess extreme acute toxicity to most bee species, with an LD<sub>50</sub> in the ranges of nanograms per individual. Studies identify the orchard mason bee *Osmia lignaria* as the most susceptible to lethal and sublethal detriments from continued exposure to neonics (specifically clothianidin), followed by *A. mellifera*, *B. terrestris*, *Megachile rotundata*, and other members of the *Apis* and *Bombus* genera, in that order<sup>86</sup>. Dust scattering, in particular, has been proposed as a second major source of neonicotinoid ingestion, in addition to consumption of food. Despite the advent of improved seed coating techniques, expulsion of neonicotinoid particles into the air are prone to occur in large quantities due to agrotech limitations. Neonicotinoids typically remain airborne after being adsorbed by larger gaseous particles, including water vapor. An increase in humidity has been established to have a positive correlation on the quantity of insecticide absorbed, as has increased sunlight and temperature, although the reasons for this phenomenon are currently under active research<sup>87</sup>. Airborne particles are not only a threat due to their physiological impact on active worker bees, but also to the hive, in both indirect and direct fashion; if in close proximity to an application of neonicotinoids, a colony is susceptible to direct airflow containing contaminants, and there is a constant issue of the contaminant being brought back with worker bees. Advancements in agrotech limiting the air scattering of applied insecticides would cut down on the environmental risks posed to

bees through airborne inhalation. Figure 4 depicts a summary of the different sources of neonicotinoid exposure for bees as it relates to CCD.



**Figure 4: Different sources of neonicotinoid exposure to bees in agricultural settings.**

Sublethal doses of neonics have been associated with reduced locomotion, transportation, foraging adaptability, learning, and olfactory response (observed in both field and semi-field settings)<sup>88</sup>. Field-realistic testing on the effect of neonics on worker bees finds reduced spatial awareness and avoidance of predators in affected individuals. Imidacloprid and clothianidin exposure has been shown to additionally negatively affect reproductive capability and the number of active bees in a hive, which is a predecessor to many forms of CCD<sup>89</sup>. Thus, there is a need to better understand the biophysiological methods by which neonicotinoids affect the metabolism and homeostasis of affected bees.

The honeybee brain contains a variety of nAChR, promoted by the number of different possible subunits and alternative splicing during transcription<sup>90</sup>. However, the effect of imidacloprid is seen to be most adverse when binding to the heteromeric nAChR  $\alpha 4\beta 2$  and the homomeric  $\alpha 1$  and  $\alpha 2$  receptors<sup>91</sup>. The limitation of signaling pathways has a wide variety of negative homeostatic effects on bees, as caused by the inability for signals to induce protein production and other cell functions at normal rates. Downregulation of various housekeeping genes in bees from CCD-positive colonies including vitellogenin (long-term memory), catalase (detoxification), and apidaecin (antimicrobial properties) corresponded to lower levels of cognition found<sup>92</sup>. The transcription of immune defense

proteins in particular, notably defensin-1, is reduced by the presence of clothianidin, as the neonic acts as a foreign kinase inhibitor in immune defense protein synthesis pathways<sup>93</sup>. In turn, a correlation is drawn between the reduced production of immune proteins [caused by neonicotinoid presence] and the presence of the parasitic mite *Varroa destructor*, indicating that the neonicotinoids play both a direct and indirect role in the occurrence of CCD. Various studies have pointed to decreased mitochondrial activity in the dorsal lobe and hypothalamus, as well as alterations to the brain lipidome in the presence of neonicotinoids; pathways including ribosome production, oxidative phosphorylation, nicotinate/nicotinamide oxidation were all altered<sup>94</sup>. RT-qPCR analysis reveals that various hormone-regulation transcripts, including farnesol dehydrogenase, were heavily downregulated in *A. mellifera*, while the lipoprotein apolipoprotein-II like protein, was upregulated. Correspondingly, the lipid composition of select bee brains was changed and observed in accordance with reduced cognition and learning ability. In the honey bee *Apis cerana*, the lipid transport and storage protein typically found in the hypothalamus, Apolipoprotein III, was downregulated in the presence of thiamethoxam, likely due to the insecticide acting as an allosteric inhibitor<sup>95</sup>.

Changes to nuclear transcription have been stated in various studies, though few *direct* correlations between the variation in regulation and symptoms of CCD have been linked; it is more difficult to draw a direct causal relationship when discussing RNA transcripts given the complex post transcriptional changes that occur and various interaction with non-coding RNA. It should be noted that while a wide range of neonicotinoids' detrimental effects to bee species have been observed, certain species have somewhat of a natural defense against neonics of type N-cyano amidines (i.e. thiacloprid and acetamiprid): Cytochrome P450<sup>96</sup>; recognized for xenobiotic metabolism, P450 enzymes - especially CYP9Q3, and to a lesser extent, CYP9Q2 - have shown to provide limited protection to many insects from neonics with cyanoamidine functional groups (R-C≡N), including honey bees<sup>97</sup>. From their metabolic pathways, P450 enzymes possess the ability to convert limited quantities of neonicotinoids → glutathione. However, this oxidative process is substrate-limited, and thus is not as effective in dealing with chronic buildup of neonicotinoids, as it occurs in most real-life scenarios.

Given the extensive impact of neonicotinoids in relation to CCD, restrictions have been placed on the use of the insecticides in proximity to registered bee colonies; later sections outline the specific regulations. The linkage of neonics to different physiological aspects of bees has been for the most part well-described, although further recognition of the effect of RNA transcript regulation changes is needed to provide a more comprehensive view on the detrimental effects of neonics on bees. The example of bees speaks to a larger environmental concern about the changes that biotransformations and bioaccumulation of neonicotinoids can elicit in environments, as well as their effect on the balance of ecosystems.

# Threats Posed to Humans

## Pathways of Exposure

On the basis of the effects of neonicotinoids on non-target species, a growing number of concerns are being raised surrounding the detrimental effects of the insecticides in humans. Generally, neonics pose lower threats to mammalian species due to a lower affinity for nAChR subunits found solely (and abundantly) in mammals in comparison with insect-specific receptors<sup>98</sup>. However, cases of their toxicity, specifically following direct inhalation or consumption, have been the subject of various studies. Here, the sublethal and lethal effects of acute and chronic neonicotinoid exposure are discussed, and the molecular mechanisms by which neonics interact with nAChRs are discussed. The impact of reduced signal propagation on protein synthesis, cell regulation, and glucose metabolism, amongst other changes, are noted in cases of human exposure. Additionally, a note is presented on the presence of neonicotinoids in food, as well as the effects of the resulting bioaccumulation in the human body.

Neonicotinoids, like most insecticides, have a very low sorption coefficient, meaning stagnation occurs at ground level, where exposure to humans is higher. When exposed to neonicotinoids, metabolic and homeostatic changes are noted in tested subjects. There has been limited *in vivo* experimentation on the modes of entry for neonicotinoids into humans given the toxic effect in higher quantities. Limited studies find a host of potential exposures, with agriculture as a primary source of neonic uptake. An analysis of 173 studies from 1988 to 2022 found surface water contamination as a result of neonicotinoid adhesion to surface water pollutants and leaching were major sources of entry into agricultural land water supplies<sup>99</sup>. In water, neonicotinoids are susceptible to degradation pathways through both bulk water hydrolysis and microbes. Recently, biomonitoring of pesticidal and specifically, insecticidal presence in humans has moved towards urine sampling, as intact insecticides are far harder to track through traditionally used bioassays. The presence of cyclic urea, 6-chloronicotinic acid, and N-methyl-thiamethoxam in urine samples of individuals exposed to contaminated well water suggest the same, as found by Thompson et al<sup>38</sup>. Another urine-excretion sampling found the presence of acetamiprid and thiamethoxam in human urine following routine insecticidal applications on agricultural land<sup>100</sup>. A positive, causal link was determined between the quantity of neonicotinoids applied (and thereby, exposed to) and the quantity of acetamiprid and thiamethoxam found in the selected urine samples (0.13 $\mu\text{g}$  per 100g applied,  $p < 0.05$ ). Seccia et al. [2005] determined through liquid chromatography-mass spectroscopy that while testing for a 100  $\mu\text{gL}^{-1}$  presence of neonicotinoids in public drinking water, acetamiprid, imidacloprid, thiacloprid, and thiamethoxam were found at average levels of 102, 87, 101, and 89  $\mu\text{gL}^{-1}$ , respectively<sup>101</sup>.

Nomura et al. [2013] identified the presence of dinotefuran, 6-chloronicotinic acid, and its conjugate 3-furoic acid in a sample of Japanese farmers' urine<sup>100</sup>. Deconjugation using metabolites and glucuronic acid revealed the further presence of imidacloprid and thiamethoxam, both of which were part of the maize seed coatings being used by the samples. In a similar sampling, the presence of the neonicotinoids thiamethoxam, thiacloprid, imidacloprid, clothianidin, acetamiprid, nitenpyram, and dinotefuran (in decreasing order of concentration) were identified in >50 Japanese samples with prior history of neonicotinoid spraying applications. The same experimental analysis finds an increase in the levels of clothianidin reported in sampled women when compared to an earlier 1994 experiment. Furthermore, the presence of imidacloprid and thiamethoxam in the 2011 study were not present in the findings of the earlier experiment. A potential explanation for this change is over this time period, neonicotinoids rose in popularity compared to organophosphorus compounds and carbamates, becoming the most widely used class of insecticides in Japan.

For non-agricultural-based individuals, exposure to neonicotinoids remains limited. Regardless, a number of studies aimed to identify the trends in neonics in food products have noted minute quantities on or in vegetable products, bovine milk, leafy greens, and other consumable items. The United States Department of Agriculture estimates imidacloprid in 81% of sweet bell peppers and broccoli and 57% of grapes produced in the US. Further, ~46, 30, 24, and 21 percent of cherry, apple, pear, and strawberry samples, respectively, collected from nationwide United States samples suggests persistence of acetamiprid in a systematic nature<sup>9</sup>. In tested leafy greens (kale, spinach, and cilantro), the same study indicates maximum residue levels of 1.4-1.6 acetamiprid parts per million. Residue data characterized for daily dietary intake of neonicotinoids found the presence of more than one neonic in over 90% of bovine milk used for human consumption<sup>102</sup>; tested Chinese milk possessed medians of 0.1 - 3.1  $\mu\text{gL}^{-1}$  for acetamiprid, N-desmethyl acetamiprid, and imidacloprid. The geographical techniques used for farming in northwestern China were identified as primary causes for the increased contamination; inorganic farming paired with elevated levels of neonicotinoid applications prove to be sources of entrance into bovine water and feed. While these and other studies support the idea of urban exposure through food contamination, the quantities of exposure remain far lower than in agricultural settings, and there has been little evidence of noteworthy changes in metabolism or homeostasis in humans.

Unfortunately, an ongoing challenge is neonicotinoid poisoning through consumption in highly toxic quantities. Over a hundred cases of fatal neonicotinoid-related poisonings have been observed, cumulative of mainly ingestion of branded insecticides<sup>103</sup>. As such, governmental regulations on the use of the insecticides have been modified, though special provisions vary from region to region. Unlike carbamates, organophosphates, and organochlorine compounds though, the toxicity of neonicotinoids is relatively smaller, with only <2.9% of attempted ingestion resulting in death (differences in medical treatment considered)<sup>103</sup>. Barring intentional ingestion, occupational hazard,

and dietary exposure (including honey), the mechanisms by which humans interact with notable levels of neonics.

## Molecular Action & Physiological Effects

Initial approval for the use of neonicotinoids was based on the premise of affinity to mostly/solely to insect nAChRs; however, recent research has identified a host of negative effects in humans at sublethal doses<sup>104</sup>. Neonicotinoids are found to be most effective against  $\alpha 4\beta 2$  acetylcholine receptors, which comprise the majority of insect acetylcholine receptors, but only a fraction in humans<sup>105</sup>. However, this receptor is found in an elevated spatial concentration specifically in the thalamus region of the brain. Exposure to neonicotinoids in humans acts as a competitive inhibitor with acetylcholine, vying for binding space on acetylcholine receptors. However, the inability for effective hydrolysis by acetylcholinesterase means successive electric propagation and overstimulation. *In vitro*, a 300  $\mu\text{M}$  solution of clothianidin was observed to have a similar effect to a 2 mM concentration of acetylcholine on the  $\alpha 4\beta 2$  receptor<sup>106</sup>. A similar result was observed for imidacloprid and thiamethoxam, indicating a high affinity for the protein, although demonstrating a lower efficacy than nicotine. Accordingly, acute exposure to neonicotinoids as described in field studies cause mild overstimulations of not only  $\alpha 4\beta 2$ , but also  $\alpha 7$  homomeric receptors on the basis of interactions between hydrophilic regions<sup>5</sup>. Again, lower efficacy in comparison with insect nicotinic acetylcholine receptors are observed.

Toxicity has been described mainly on antagonistic action on the  $\alpha 4\beta 2$  receptor; this receptor is implicated in learning and following post-synaptic excitation, permeability of  $\text{Na}^+$  and  $\text{K}^+$  ions<sup>107</sup>. In human cases, there have been no recognized antidotes for neonics and their antagonistic action, disrupting homeostasis<sup>108</sup>. Here the effects of the mild abnormal signaling on both normal signal propagation and protein activity is discussed.

*In vitro* genotoxicity of human blood lymphocyte cells was observed in a linear fashion following thiacloprid, clothianidin, and imidacloprid applications<sup>109</sup>. When applied in high concentrations (10x sublethal constant), >80% of nuclear DNA was observed to have damage at ends of helices, acting as oxidative reagent, and tail shortening. Genetic instability through the formation of micronuclei and exchanges between sister chromatids during cell division was also identified. Such mutations have been linked with oncogenesis and improper gene transcription<sup>110</sup>. In samples containing over 1000 individuals, patients identified with exposure to one or more neonics experienced medically significant outcomes, including chest pain, nausea, red eye, inflammation, headache, dizziness, and dermal irritation, amongst others<sup>111</sup>. The most serious outcomes described were hypertension and tachycardia (<1% of samples), although neither of these symptoms prolonged and dissipated within 10-15 hours post-ingestion. An observational study by Mohamed et al. [2009]

found in 56 self-ingestion cases found similar results in patients post-ingestion<sup>112</sup>. A 70-patient analysis of cases of self-ingestion reported to the Taiwan Poison Center in 2009 reported that in addition to the mentioned symptoms, in 57 patients, mild muscular tetanus and paralysis of connective muscles were described<sup>113</sup>. The root cause was identified as the overstimulation of acetylcholine receptors in the hypothalamus, which in turn propagates neural signals to neuromuscular junctions. Keil, Daniels, and Hertz-Picciotto [2014] described the conjunction between early life exposure to neonicotinoids, specifically imidacloprid, and the development of autism spectrum disorder retrospectively<sup>114</sup>. An odds ratio of 1.3 was determined for early life (blastula stage) exposure to imidacloprid and chances of developing autism when compared to a control. A negative regression model was described at a 95% confidence interval between trimester and exposure to neonics against odds of developing autism. It should be noted that the disorder is caused by a host of genetic and neural differences, and the study presents a non-causal relationship that simply describes a trend. A 2014 observational study found out of 101 case studies, 38% of cases of offspring contingent heart defects could be attributed in part to the influence of neonicotinoids. Specifically, the limitation of genetic development through instability was noted in mid-pregnancy reports, and resultantly, a number of offspring were born with coarctation of the aorta (n = 74), hypoplastic left heart syndrome (n = 59), or ventricular septal defects (n = 93). Yang et al. examined the same sample data for neural tube defects and found that offspring whose mothers resided within a 500m radius to a pesticidal application location were at significantly higher risk of developing anencephaly, spina bifida, or cleft palate<sup>115</sup>.

While many other articles of research suggest similar sublethal or lethal effects of neonicotinoids (depending on the quantity exposed to or ingested), it is important to recognize limitations in determining neonics as a singular cause of varying phenotypes, and moreover, identifying neonics *in vivo*.

## Bans & Restrictions on Neonicotinoid Usage

Given the varying environmental and toxic effects of neonicotinoids described in non-target species, there is a growing movement to restrict and/or outright ban the use of them for agricultural or urban uses. Here, legislation regarding the restriction of neonicotinoids is discussed for three leading regions of usage/production of the chemicals.

### Europe

The 2004 Stockholm Convention placed flat bans on the use of organochlorines including DDT, HCH, and lindane, recommending neonicotinoids (amongst others) as a more specific,

environmentally-conscious choice. However, finding on the sublethal and lethal effect of the insecticides on bees, aquatic organisms, and certain amphibians created push-back against their use. In 2009, Italy became the first European country to pose limitations on the application of neonicotinoids; its use on maize in the form of foliar sprays and seed coatings was completely outlawed<sup>116</sup>. The United Kingdom and France followed suit with restrictions being placed on the use of imidacloprid in agricultural settings with high pollination activity. The European Union (EU) began to recommend organic alternatives to neonicotinoids in the 2010s due to rising concerns of the effect of neonicotinoids on non-target species, with a special note on the acute presence of neonics in maize (EFSA). Three years later, the EU heavily restricted the use of seed coatings containing clothianidin, thiamethoxam, and imidacloprid, which were the leading insecticides used at the time<sup>117</sup>. The restriction was placed on pollinator-attracting economic crops, including maize, oilseed rape, and sunflower following a judgement that the insecticides posed a credible threat to non-target insect species, notably bees. A confirmatory hearing was made in February of 2018, expanding the restrictions to non-greenhouse, outdoor uses in all EU nations. The decision comes on the back of a call for the continuation of neonicotinoid usage in the farming community given its economic importance. Temporary derogations were granted in France based on new provincial, agricultural laws in 2020, granting special access to both imidacloprid and thiamethoxam<sup>118</sup>. Applications authorized both seed coatings and systematic spraying on a free range of economic crops, including maize, soybean, and other pollinator crops. However, the temporary lift of the ban was revoked in 2023 following a tertiary hearing by the European Union. Thus, neonicotinoids are authorized for application only on non-pollinator crops, as directed by the EU's food and safety organization, EFSA. In addition, the export of neonicotinoids - once a primary pesticide produced in Europe - has been restricted through the form of tariff and trade regulation requirements.

## North America

Neonicotinoids are not subject to strict federal restrictions in the United States as it relates to application method, but statewide policies vary in their leniency towards its usage. Many states, including Minnesota, New York, Nevada, and Colorado have moved to ban the use of neonicotinoids on conservation land, further regulate the labeling of pollinator-friendly economic crops, and limit the use of neonics in seed treatments<sup>119</sup>. Furthermore, state regulations on urban usage on lawns, fields, and outdoor settings have been enacted. Regardless, the United States Environmental Protection Agency maintains that neonicotinoids are still a recommended insecticide in dealing with nematodes, thrips, aphids, beetles, and other pests. An initial ban on neonicotinoids existed in all provinces of Canada from 2010 to 2021, citing environmental dangers from runoff and aggregation in water sources. However, Health Canada reversed this ban in 2021. Imidacloprid, thiamethoxam, and



clothianidin are permitted under new federal regulations to be used in foliar sprays and pollinator-friendly seed coatings. In agrarian North American communities, such as those found in parts of Latin America and Mexico, regulations on neonics are sparse, and the class continues to be the most widely used group of insecticides<sup>120</sup>.

## Asia

In other agrarian states, regulation on the use of neonicotinoids continues to be sparse. Asian nations, including India, China, and Indonesia, continue to be some of the leading consumers of imidacloprid, thiamethoxam, acetamiprid, and clothianidin in seed coating, sprays, and powder applications<sup>118</sup>. This is the case for urban applications as well, where neonics are used primarily in targeted control of thrips, cockroaches, moths, and other related pests. The low effective dosages of neonicotinoids in comparison with organophosphates, organochlorines, carbamates, and pyrethroids - major classes of economic insecticides - allow for limited regulation and restrictions. In turn, environmental damages in the form of surface runoff, groundwater contamination, and disruption of aquatic and terrestrial ecosystems have been noted in greater quantities in India and China<sup>121</sup>. In India, the only federal restriction placed on neonics was a temporary ban on imidacloprid and its relative fipronil in 2018 due to toxic effect on non-target species, including bees and other pollinators. However, the ban was overturned following several protests citing the importance of neonicotinoids in farming communities as an effective measure to displace pests. Currently, limited legislation is proposed in Indonesia and China to restrict the use of neonicotinoids on pollinator-friendly plant species, including maize and soy.

## Future of Neonicotinoids

Neonicotinoids continue to remain the most widely-used class of chemical insecticides worldwide and will likely continue to remain so for the next decade. Their main advantages over comparable insecticide classes are the increased [insect] specificity and cheaper cost of production. Furthermore, while organophosphorus compounds, organochlorines, pyrethroids, and carbamates all are measured in kilograms per acre, neonics are one of the first groups of insecticides with application quantities in the grams per acre. This property is not at the cost of effectiveness, as similar class comparisons yield equally similar LD<sub>50</sub> ranges. Specific soil pests, including white grubs, roundworms, and earthworms, are more easily contained through the use of neonics in systemic applications, contrasting the excessive quantity of either organochlorines or organophosphorus compounds needed prior. Imidacloprid, thiamethoxam, and clothianidin lead applications of insecticides on sugarcane,

maize, soy, and other stalk plants, and cover over 150 million acres of land in the United States (leading user globally) alone.

However, the environmental risks associated with neonicotinoids – and for that matter, all major insecticide classes – are concerning for both their impact on humans in close proximity to their application and other non-target species, notably honeybees. A new movement of eco-friendly farming techniques are on the rise, limiting the use of chemical insecticides, fertilizers, and other agrochemical techniques or substances, with the intention of a more sustainable and environmentally conscious crop production cycle. The use of microbial insecticides – bacterial communities which produce biotoxins with insecticidal properties – has also gained traction. The most widely used microbial insecticide is of the crystalline (cry) protein family from the gram-positive *Bacillus thuringiensis*, which binds to glycosyl-phosphatidyl-inositol anchored ALP or APN receptors in insect midgut or posterior regions<sup>122</sup>. The main advantage of a microbial insecticide over a chemical insecticide is the heightened target specificity with little to no risk of negative impact on non-target species; proteins synthesized from ‘insecticidal microbes’ have 3D structures fit for the structure of insect midgut (or other target) receptors specifically, which differ greatly in spatial configuration with human and mammalian receptors of similar function. Unlike such receptors, nAChRs, the target receptor of most chemical insecticides, shares many analog similarities in mammals and insects, thus explaining the impact on non-target species. In addition, a new generation of chemical insecticides, mainly composed of anthranilic diamides, are underway in trial and production<sup>123</sup>. The potential of alleviating the environmental risks associated with neonicotinoid usage is a prospect gaining traction in both agricultural and legislative settings, being set a precedent of new agricultural and insecticidal technology.

While alternatives to neonicotinoid [and chemical] insecticides are an exciting and upcoming area of research and a potential new frontier of maintaining crop output, their tangible applications are still limited. Bioinsecticides are extremely specific in their target and thus cannot be used against a wider range of feeding insects like neonicotinoids. Microbial insecticides from *B. thuringiensis* or other members of the Bacillus family (which produce Cry proteins and homologous substances) must additionally be stored in extremely cold temperatures and applied in quantities far greater than required for effective neonicotinoid applications. As a result, the economic advantages of neonicotinoids over both newer and older classes of insecticides have been a primary reason of their continued success. In developing nations, the monetary benefits of selecting and using a cheaper insecticide such as imidacloprid over more expensive bioinsecticides (also limited by availability) is often a large factor in deciding which insecticide to purchase. As for organochlorines, organophosphorus compounds, carbamates, and pyrethroids, existing legislation set forward regionally

and globally (e.g. Stockholm Convention, 2004) have limited their ability to compete with neonicotinoids.

It is key that neonicotinoids, given their advantages, are used sustainably with the larger effects on the environment in mind. Applications must be mindful of the presence of surface water bodies, groundwater sources, or large numbers of non-target species within radii of usage. Proper farming technique (weather forecasting, spray broom down, etc.) in preventing spray drift has additionally shown to reduce exposure to non-target species, including those that interact with plants where neonicotinoids are applied<sup>124</sup>. A special note to bee colonies in the vicinity of application when considering use may help mitigate chronic exposure to neonicotinoids and its negative effects. Regular tracking of water quality and leaching of insecticides into bodies would indicate both the safety of the water for consumption/use as well as the quantity of runoff. If such factors are maintained, *ceteris paribus*, environmental damages of neonicotinoids can be reduced. Thus, the future of neonicotinoid usage is dependent on the advent of new insecticidal technologies, legislative restriction, and maintaining of proper safety practices when dealing with the insecticide. Only time will tell whether or not neonics will continue as the most widely used chemical insecticide.

## References

1. Tudi M, Ruan HD, Wang L, et al. Agriculture Development, Pesticide Application and Its Impact on the Environment. *Int J Environ Res Public Health*. 2021;18(3):1-24. doi:10.3390/IJERPH18031112
2. Oerke EC. Crop losses to pests. *J Agric Sci*. 2006;144(1):31-43. doi:10.1017/S0021859605005708
3. Alavanja MCR. Pesticides Use and Exposure Extensive Worldwide. *Rev Environ Health*. 2009;24(4):303. doi:10.1515/REVEH.2009.24.4.303
4. Miglani R, Bisht SS. World of earthworms with pesticides and insecticides. *Interdiscip Toxicol*. 2020;12(2):71-82. doi:10.2478/INTOX-2019-0008
5. Thany SH. Molecular Mechanism of Action of Neonicotinoid Insecticides. *Int J Mol Sci*. 2023;24(6). doi:10.3390/IJMS24065484
6. Mundhe SA, Birajdar S V., Chavan SS, Pawar NR. Imidacloprid Poisoning: An Emerging Cause of Potentially Fatal Poisoning. *Indian J Crit Care Med*. 2017;21(11):786. doi:10.4103/IJCCM.IJCCM\_152\_17
7. Hladik ML, Main AR, Goulson D. Environmental Risks and Challenges Associated with Neonicotinoid Insecticides. *Environ Sci Technol*. 2018;52(6):3329-3335. doi:10.1021/ACS.EST.7B06388
8. Lee YJ, Kang JK, Park SJ, Lee CG, Moon JK, Alvarez PJJ. Photocatalytic degradation of neonicotinoid insecticides using sulfate-doped Ag<sub>3</sub>PO<sub>4</sub> with enhanced visible light activity. *Chemical Engineering Journal*. 2020;402:126183. doi:10.1016/J.CEJ.2020.126183
9. Craddock HA, Huang D, Turner PC, Quirós-Alcalá L, Payne-Sturges DC. Trends in neonicotinoid pesticide residues in food and water in the United States, 1999-2015. *Environ Health*. 2019;18(1):1-16. doi:10.1186/S12940-018-0441-7/FIGURES/5
10. Berens MJ, Capel PD, Arnold WA. Neonicotinoid Insecticides in Surface Water, Groundwater, and Wastewater Across Land-Use Gradients and Potential Effects. *Environ Toxicol Chem*. 2021;40(4):1017. doi:10.1002/ETC.4959
11. Jayaraj R, Megha P, Sreedev P. Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. *Interdiscip Toxicol*. 2016;9(3-4):90. doi:10.1515/INTOX-2016-0012
12. vanEngelsdorp D, Evans JD, Saegerman C, et al. Colony Collapse Disorder: A Descriptive Study. *PLoS One*. 2009;4(8):e6481. doi:10.1371/journal.pone.0006481
13. Feuer H, Lawrence JP. Alkyl nitrate nitration of active methylene compounds. VI. Synthesis of .alpha.-nitroalkyl heterocyclics. *J Am Chem Soc*. 1969;91(7):1856-1857. doi:10.1021/ja01035a049

14. Schroeder ME, Flattum RF. The mode of action and neurotoxic properties of the nitromethylene heterocycle insecticides. *Pestic Biochem Physiol.* 1984;22(2):148-160. doi:10.1016/0048-3575(84)90084-1
15. Sheets L. Imidacloprid: a neonicotinoid insecticide. Accessed November 8, 2023. [https://www.researchgate.net/publication/313511293\\_Imidacloprid\\_a\\_neonicotinoid\\_insecticide](https://www.researchgate.net/publication/313511293_Imidacloprid_a_neonicotinoid_insecticide)
16. Maloney EM, Liber K, Headley J V., Peru KM, Morrissey CA. Neonicotinoid insecticide mixtures: Evaluation of laboratory-based toxicity predictions under semi-controlled field conditions. *Environmental Pollution.* 2018;243:1727-1739. doi:10.1016/J.ENVPOL.2018.09.008
17. Heitholt JJ, Hodgson RH, Tworkoski TJ. Toxicity and uptake of nitroguanidine in plants. *Bull Environ Contam Toxicol.* 1990;44(5):751-758. doi:10.1007/BF01701798/METRICS
18. Keong CY. The United Nations environmental education initiatives: The green education failure and the way forward. *Global Environmental Sustainability.* Published online January 1, 2021:289-349. doi:10.1016/B978-0-12-822419-9.00006-0
19. Buszewski B, Bukowska M, Ligor M, Staneczko-Baranowska I. A holistic study of neonicotinoids neuroactive insecticides—properties, applications, occurrence, and analysis. *Environ Sci Pollut Res Int.* 2019;26(34):34723. doi:10.1007/S11356-019-06114-W
20. Purves D, Augustine GJ, Fitzpatrick D, et al. Acetylcholine. Published online 2001. Accessed November 8, 2023. <https://www.ncbi.nlm.nih.gov/books/NBK11143/>
21. Hyde EG, Boyer A, Tang P, Xu Y, Abramson SN. Irreversible Inhibitors of Nicotinic Acetylcholine Receptors: Isolation and Structural Characterization of the Biologically Active Solvolysis Products of Bipinnatin-A and Bipinnatin-C. *J Med Chem.* 1995;38(12):2231-2238. doi:10.1021/jm00012a023
22. Tomizawa M, Casida JE. Structure and diversity of insect nicotinic acetylcholine receptors. *Pest Manag Sci.* 2001;57(10):914-922. doi:10.1002/PS.349
23. Costas-Ferreira C, Faro LRF. Neurotoxic Effects of Neonicotinoids on Mammals: What Is There beyond the Activation of Nicotinic Acetylcholine Receptors?—A Systematic Review. *Int J Mol Sci.* 2021;22(16). doi:10.3390/IJMS22168413
24. Nashmi R, Dickinson ME, McKinney S, et al. Assembly of  $\alpha 4\beta 2$  Nicotinic Acetylcholine Receptors Assessed with Functional Fluorescently Labeled Subunits: Effects of Localization, Trafficking, and Nicotine-Induced Upregulation in Clonal Mammalian Cells and in Cultured Midbrain Neurons. *The Journal of Neuroscience.* 2003;23(37):11554. doi:10.1523/JNEUROSCI.23-37-11554.2003
25. Pan H, Liu Y, Liu B, et al. Lethal and sublethal effects of cycloxaprid, a novel cis-nitromethylene neonicotinoid insecticide, on the mirid bug *Apolygus lucorum*. *J Pest Sci (2004).* 2014;87(4):731-738. doi:10.1007/S10340-014-0610-6
26. Zhang P, Ren C, Sun H, Min L. Sorption, desorption and degradation of neonicotinoids in four agricultural soils and their effects on soil microorganisms. *Sci Total Environ.* 2018;615:59-69. doi:10.1016/J.SCITOTENV.2017.09.097

27. Schiff L, Dreibelbis FR. Movement of water within the soil and surface runoff with reference to land use and soil properties. *Eos, Transactions American Geophysical Union*. 1949;30(3):401-411. doi:10.1029/TR030I003P00401
28. Pietrzak D, Kania J, Kmiecik E, Malina G, Wątor K. Fate of selected neonicotinoid insecticides in soil–water systems: Current state of the art and knowledge gaps. *Chemosphere*. 2020;255. doi:10.1016/J.CHEMOSPHERE.2020.126981
29. Shi Y, Wang S, Xu M, Yan X, Huang J, Wang H wei. Removal of neonicotinoid pesticides by adsorption on modified *Tenebrio molitor* frass biochar: Kinetics and mechanism. *Sep Purif Technol*. 2022;297:121506. doi:10.1016/J.SEPPUR.2022.121506
30. Pagano M, Stara A, Aliko V, Faggio C. Impact of Neonicotinoids to Aquatic Invertebrates—In Vitro Studies on *Mytilus galloprovincialis*: A Review. *Journal of Marine Science and Engineering* 2020, Vol 8, Page 801. 2020;8(10):801. doi:10.3390/JMSE8100801
31. Butcherine P, Kelaher BP, Taylor MD, Lawson C, Benkendorff K. Acute toxicity, accumulation and sublethal effects of four neonicotinoids on juvenile Black Tiger Shrimp (*Penaeus monodon*). *Chemosphere*. 2021;275:129918. doi:10.1016/J.CHEMOSPHERE.2021.129918
32. Bartlett AJ, Hedges AM, Intini KD, et al. Acute and chronic toxicity of neonicotinoid and butenolide insecticides to the freshwater amphipod, *Hyalella azteca*. *Ecotoxicol Environ Saf*. 2019;175:215-223. doi:10.1016/J.ECOENV.2019.03.038
33. Siregar P, Suryanto ME, Chen KHC, et al. Exploiting the Freshwater Shrimp *Neocaridina denticulata* as Aquatic Invertebrate Model to Evaluate Nontargeted Pesticide Induced Toxicity by Investigating Physiologic and Biochemical Parameters. *Antioxidants*. 2021;10(3):391. doi:10.3390/antiox10030391
34. Tian X, Hong X, Yan S, et al. Neonicotinoids caused oxidative stress and DNA damage in juvenile Chinese rare minnows (*Gobiocypris rarus*). *Ecotoxicol Environ Saf*. 2020;197:110566. doi:10.1016/J.ECOENV.2020.110566
35. Morrissey CA, Mineau P, Devries JH, et al. Neonicotinoid contamination of global surface waters and associated risk to aquatic invertebrates: A review. *Environ Int*. 2015;74:291-303. doi:10.1016/J.ENVINT.2014.10.024
36. Carrard N, Foster T, Willetts J. Groundwater as a Source of Drinking Water in Southeast Asia and the Pacific: A Multi-Country Review of Current Reliance and Resource Concerns. *Water* 2019, Vol 11, Page 1605. 2019;11(8):1605. doi:10.3390/W11081605
37. Labaugh JW, Rosenberry DO, Winter TC. Groundwater contribution to the water and chemical budgets of Williams Lake, Minnesota, 1980-1991. *Canadian Journal of Fisheries and Aquatic Sciences*. 1995;52(4):754-767. doi:10.1139/F95-075
38. Thompson DA, Hruby CE, Vargo JD, Field RW. Occurrence of neonicotinoids and sulfoxaflor in major aquifer groups in Iowa. *Chemosphere*. 2021;281. doi:10.1016/J.CHEMOSPHERE.2021.130856

39. Alford AM, Krupke CH. Movement of the Neonicotinoid Seed Treatment Clothianidin into Groundwater, Aquatic Plants, and Insect Herbivores. *Environ Sci Technol*. 2019;53(24):14368-14376. doi:10.1021/ACS.EST.9B05025/SUPPL\_FILE/ES9B05025\_SI\_001.PDF
40. Li AJ, Kannan K. Profiles of urinary neonicotinoids and dialkylphosphates in populations in nine countries. *Environ Int*. 2020;145:106120. doi:10.1016/J.ENVINT.2020.106120
41. Zhang H, Zhu K, Du J, et al. Serum concentrations of neonicotinoids and their characteristic metabolites in elderly population from South China: Association with osteoporosis. *Environ Res*. 2022;203:111772. doi:10.1016/J.ENVRES.2021.111772
42. Pang S, Lin Z, Zhang W, Mishra S, Bhatt P, Chen S. Insights Into the Microbial Degradation and Biochemical Mechanisms of Neonicotinoids. *Front Microbiol*. 2020;11:526444. doi:10.3389/FMICB.2020.00868/BIBTEX
43. Streletskii R, Astaykina A, Krasnov G, Gorbatov V. Changes in Bacterial and Fungal Community of Soil under Treatment of Pesticides. *Agronomy 2022, Vol 12, Page 124*. 2022;12(1):124. doi:10.3390/AGRONOMY12010124
44. Akter S, Hulugalle NR, Jasonsmith J, Strong CL. Changes in soil microbial communities after exposure to neonicotinoids: A systematic review. *Environ Microbiol Rep*. Published online 2023. doi:10.1111/1758-2229.13193
45. Labrie G, Gagnon AÈ, Vanasse A, Latraverse A, Tremblay G. Impacts of neonicotinoid seed treatments on soil-dwelling pest populations and agronomic parameters in corn and soybean in Quebec (Canada). *PLoS One*. 2020;15(2):e0229136. doi:10.1371/JOURNAL.PONE.0229136
46. Zhao YX, Wang L, Chen KX, et al. Biodegradation of flonicamid by *Ensifer adhaerens* CGMCC 6315 and enzymatic characterization of the nitrile hydratases involved. *Microb Cell Fact*. 2021;20(1):1-13. doi:10.1186/S12934-021-01620-4/FIGURES/6
47. Cycoń M, Piotrowska-Seget Z. Community structure of ammonia-oxidizing archaea and ammonia-oxidizing bacteria in soil treated with the insecticide imidacloprid. *Biomed Res Int*. 2015;2015. doi:10.1155/2015/582938
48. Parizadeh M, Mimee B, Kembel SW. Neonicotinoid Seed Treatments Have Significant Non-target Effects on Phyllosphere and Soil Bacterial Communities. *Front Microbiol*. 2021;11:619827. doi:10.3389/FMICB.2020.619827/BIBTEX
49. Zhao S, Dong J, Jeong HJ, Okumura K, Ueda H. Rapid detection of the neonicotinoid insecticide imidacloprid using a quenchbody assay. *Anal Bioanal Chem*. 2018;410(17):4219-4226. doi:10.1007/S00216-018-1074-Y
50. Yang X, Xie W, Li RM, et al. RNA interference-mediated knockdown of the hydroxyacid-oxoacid transhydrogenase gene decreases thiamethoxam resistance in adults of the whitefly *Bemisia tabaci*. *Sci Rep*. 2017;7. doi:10.1038/SREP41201
51. Verebová V, Želonková K, Holečková B, Staničová J. The effect of neonicotinoid insecticide thiacloprid on the structure and stability of DNA. *Physiol Res*. 2019;68(Suppl 4):S459-S466. doi:10.33549/PHYSIOLRES.934385

52. Chen T, Dai YJ, Ding JF, Yuan S, Ni JP. N-demethylation of neonicotinoid insecticide acetamiprid by bacterium *Stenotrophomonas maltophilia* CGMCC 1.1788. *Biodegradation*. 2008;19(5):651-658. doi:10.1007/S10532-007-9170-2
53. Liu H, Tang X, Xu X, Dai Y, Zhang X, Yang Y. Potential for phytoremediation of neonicotinoids by nine wetland plants. *Chemosphere*. 2021;283:131083. doi:10.1016/J.CHEMOSPHERE.2021.131083
54. Elumalai P, Yi X, Chen Z, et al. Detection of Neonicotinoids in agriculture soil and degradation of thiacloprid through photo degradation, biodegradation and photo-biodegradation. *Environmental Pollution*. 2022;306:119452. doi:10.1016/j.envpol.2022.119452
55. Guo L, Yang W, Cheng X, et al. Degradation of neonicotinoid insecticide acetamiprid by two different nitrile hydratases of *Pseudaminobacter salicylatoxidans* CGMCC 1.17248. *Int Biodeterior Biodegradation*. 2021;157:105141. doi:10.1016/j.ibiod.2020.105141
56. Elzaki MEA, Miah MA, Wu M, et al. Imidacloprid is degraded by CYP353D1v2, a cytochrome P450 overexpressed in a resistant strain of *Laodelphax striatellus*. *Pest Manag Sci*. 2017;73(7):1358-1363. doi:10.1002/ps.4570
57. Wang J, Liu Y, Yin R, Wang N, Xiao T, Hirai H. RNA-Seq analysis of *Phanerochaete sordida* YK-624 degrades neonicotinoid pesticide acetamiprid. *Environ Technol*. 2023;44(15):2280-2287. doi:10.1080/09593330.2022.2026488
58. Fenoll J, Garrido I, Hellín P, Flores P, Navarro S. Photodegradation of neonicotinoid insecticides in water by semiconductor oxides. *Environmental Science and Pollution Research*. 2015;22(19):15055-15066. doi:10.1007/s11356-015-4721-2
59. Cheonh PYY, Kansedo J, Lau JSY, Tan YH. Renewable Biomass Wastes for Biohydrogen Production. In: *Comprehensive Renewable Energy*. Elsevier; 2022:273-298. doi:10.1016/B978-0-12-819727-1.00091-1
60. Liang R, Tang F, Wang J, Yue Y. Photo-degradation dynamics of five neonicotinoids: Bamboo vinegar as a synergistic agent for improved functional duration. *PLoS One*. 2019;14(10):e0223708. doi:10.1371/journal.pone.0223708
61. Mörtl M, Vehovszky Á, Klátyik S, Takács E, Győri J, Székács A. Neonicotinoids: Spreading, Translocation and Aquatic Toxicity. *Int J Environ Res Public Health*. 2020;17(6):2006. doi:10.3390/ijerph17062006
62. Todey SA, Fallon AM, Arnold WA. Neonicotinoid insecticide hydrolysis and photolysis: Rates and residual toxicity. *Environ Toxicol Chem*. 2018;37(11):2797-2809. doi:10.1002/etc.4256
63. Acero JL, Real FJ, Javier Benitez F, Matamoros E. Degradation of neonicotinoids by UV irradiation: Kinetics and effect of real water constituents. *Sep Purif Technol*. 2019;211:218-226. doi:10.1016/j.seppur.2018.09.076
64. Rong Chen HYCZXLGL. Hydrolysis of a neonicotinoid: a theoretical study on the reaction mechanism of dinotefuran. Published online September 26, 2017:315-235.



65. Karmakar R, Singh SB, Kulshrestha G. Kinetics and mechanism of the hydrolysis of thiamethoxam. *Journal of Environmental Science and Health, Part B*. 2009;44(5):435-441. doi:10.1080/03601230902934785
66. Kanne DB, Dick RA, Tomizawa M, Casida JE. Neonicotinoid Nitroguanidine Insecticide Metabolites: Synthesis and Nicotinic Receptor Potency of Guanidines, Aminoguanidines, and Their Derivatives. *Chem Res Toxicol*. 2005;18(9):1479-1484. doi:10.1021/tx050160u
67. Yao YN, Song S, Huang Y, Kannan K, Sun H, Zhang T. Insights into Free and Conjugated Forms of Neonicotinoid Insecticides in Human Serum and Their Association with Oxidative Stress. *Environment & Health*. 2023;1(2):121-129. doi:10.1021/envhealth.3c00023
68. Milovica V, Turchanowa L, Khomutov AR, Khomutov RM, Caspary WF, Stein J. Hydroxylamine-containing inhibitors of polyamine biosynthesis and impairment of colon cancer cell growth. *Biochem Pharmacol*. 2001;61(2):199-206. doi:10.1016/S0006-2952(00)00549-9
69. Wei J, Wang X, Tu C, et al. Remediation technologies for neonicotinoids in contaminated environments: Current state and future prospects. *Environ Int*. 2023;178:108044. doi:10.1016/j.envint.2023.108044
70. Borsuah JF, Messer TL, Snow DD, Comfort SD, Mittelstet AR. Literature Review: Global Neonicotinoid Insecticide Occurrence in Aquatic Environments. *Water (Basel)*. 2020;12(12):3388. doi:10.3390/w12123388
71. Wang Z, Brooks BW, Zeng EY, You J. Comparative mammalian hazards of neonicotinoid insecticides among exposure durations. *Environ Int*. 2019;125:9-24. doi:10.1016/j.envint.2019.01.040
72. Carradori S, Zengin G. Patent survey on saffron and its multiple applications. In: *Saffron*. Elsevier; 2021:275-312. doi:10.1016/B978-0-12-821219-6.00008-7
73. Maini S, Medrzycki P, Porrini C. The puzzle of honey bee losses: a brief review. *Bull Insectology*. 2010;63(1):153-160.
74. vanEngelsdorp D, Hayes J, Underwood RM, Pettis J. A Survey of Honey Bee Colony Losses in the U.S., Fall 2007 to Spring 2008. *PLoS One*. 2008;3(12):e4071. doi:10.1371/journal.pone.0004071
75. Patel S, Mall P. Colony Collapse Disorder and their Causes. *Excellent Publishers*. 2020;Special Issue 11:3587-3597.
76. Stoner KA, Eitzer BD. Movement of Soil-Applied Imidacloprid and Thiamethoxam into Nectar and Pollen of Squash (*Cucurbita pepo*). *PLoS One*. 2012;7(6):e39114. doi:10.1371/journal.pone.0039114
77. Maxim L, van der Sluijs J. Seed-dressing systemic insecticides and honeybees. *Emerging Issues*. 2013;3:371-405.
78. Rortais A, Arnold G, Halm MP, Touffet-Briens F. Modes of honeybees exposure to systemic insecticides: estimated amounts of contaminated pollen and nectar consumed by different categories of bees. *Apidologie*. 2005;36(1):71-83. doi:10.1051/apido:2004071

79. Chauzat MP, Faucon JP, Martel AC, Lachaize J, Cougoule N, Aubert M. A Survey of Pesticide Residues in Pollen Loads Collected by Honey Bees in France. *J Econ Entomol.* 2006;99(2):253-262. doi:10.1093/jee/99.2.253
80. Chauzat MP, Carpentier P, Martel AC, et al. Influence of Pesticide Residues on Honey Bee (Hymenoptera: Apidae) Colony Health in France. *Environ Entomol.* 2009;38(3):514-523. doi:10.1603/022.038.0302
81. Dively GP, Kamel A. Insecticide Residues in Pollen and Nectar of a Cucurbit Crop and Their Potential Exposure to Pollinators. *J Agric Food Chem.* 2012;60(18):4449-4456. doi:10.1021/jf205393x
82. Girolami V, Mazzon L, Squartini A, et al. Translocation of Neonicotinoid Insecticides From Coated Seeds to Seedling Guttation Drops: A Novel Way of Intoxication for Bees. *J Econ Entomol.* 2009;102(5):1808-1815. doi:10.1603/029.102.0511
83. Zhang C, Wang X, Kaur P, Gan J. A critical review on the accumulation of neonicotinoid insecticides in pollen and nectar: Influencing factors and implications for pollinator exposure. *Science of The Total Environment.* 2023;899:165670. doi:10.1016/j.scitotenv.2023.165670
84. Kessler SC, Tiedeken EJ, Simcock KL, et al. Bees prefer foods containing neonicotinoid pesticides. *Nature.* 2015;521(7550):74-76. doi:10.1038/nature14414
85. Schott M, Sandmann M, Cresswell JE, et al. Honeybee colonies compensate for pesticide-induced effects on royal jelly composition and brood survival with increased brood production. *Sci Rep.* 2021;11(1):62. doi:10.1038/s41598-020-79660-w
86. van der Sluijs JP, Simon-Delso N, Goulson D, Maxim L, Bonmatin JM, Belzunces LP. Neonicotinoids, bee disorders and the sustainability of pollinator services. *Curr Opin Environ Sustain.* 2013;5(3-4):293-305. doi:10.1016/j.cosust.2013.05.007
87. Girolami V, Marzaro M, Vivan L, et al. Fatal powdering of bees in flight with particulates of neonicotinoids seed coating and humidity implication. *Journal of Applied Entomology.* 2012;136(1-2):17-26. doi:10.1111/j.1439-0418.2011.01648.x
88. Christen V, Mittner F, Fent K. Molecular Effects of Neonicotinoids in Honey Bees (*Apis mellifera*). *Environ Sci Technol.* 2016;50(7):4071-4081. doi:10.1021/acs.est.6b00678
89. Tan K, Chen W, Dong S, Liu X, Wang Y, Nieh JC. Imidacloprid Alters Foraging and Decreases Bee Avoidance of Predators. *PLoS One.* 2014;9(7):e102725. doi:10.1371/journal.pone.0102725
90. Williams GR, Troxler A, Retschnig G, et al. Neonicotinoid pesticides severely affect honey bee queens. *Sci Rep.* 2015;5(1):14621. doi:10.1038/srep14621
91. Dupuis JP, Gauthier M, Raymond-Delpech V. Expression patterns of nicotinic subunits  $\alpha 2$ ,  $\alpha 7$ ,  $\alpha 8$ , and  $\beta 1$  affect the kinetics and pharmacology of ACh-induced currents in adult bee olfactory neuropiles. *J Neurophysiol.* 2011;106(4):1604-1613. doi:10.1152/jn.00126.2011

92. Havukainen H, Münch D, Baumann A, et al. Vitellogenin recognizes cell damage through membrane binding and shields living cells from reactive oxygen species. *J Biol Chem*. 2013;288(39):28369-28381. doi:10.1074/JBC.M113.465021
93. Annoscia D, Di Prisco G, Becchimanzi A, et al. Neonicotinoid Clothianidin reduces honey bee immune response and contributes to Varroa mite proliferation. *Nature Communications* 2020 11:1. 2020;11(1):1-7. doi:10.1038/s41467-020-19715-8
94. Fent K, Schmid M, Hettich T, Schmid S. The neonicotinoid thiacloprid causes transcriptional alteration of genes associated with mitochondria at environmental concentrations in honey bees. *Environmental Pollution*. 2020;266:115297. doi:10.1016/J.ENVPOL.2020.115297
95. Kim BY, Jin BR. Apolipoprotein III from honeybees (*Apis cerana*) exhibits antibacterial activity. *Comp Biochem Physiol B Biochem Mol Biol*. 2015;182:6-13. doi:10.1016/J.CBPB.2014.11.010
96. Feyereisen R. Toxicology: Bee P450s Take the Sting out of Cyanoamidine Neonicotinoids. *Current Biology*. 2018;28(9):R560-R562. doi:10.1016/J.CUB.2018.03.013
97. Iwasa T, Motoyama N, Ambrose JT, Roe RM. Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, *Apis mellifera*. *Crop Protection*. 2004;23(5):371-378. doi:10.1016/J.CROPRO.2003.08.018
98. Zhang D, Lu S. Human exposure to neonicotinoids and the associated health risks: A review. *Environ Int*. 2022;163:107201. doi:10.1016/j.envint.2022.107201
99. Stehle S, Ovcharova V, Wolfram J, et al. Neonicotinoid insecticides in global agricultural surface waters – Exposure, risks and regulatory challenges. *Science of The Total Environment*. 2023;867:161383. doi:10.1016/j.scitotenv.2022.161383
100. Ueyama J, Nomura H, Kondo T, et al. Biological Monitoring Method for Urinary Neonicotinoid Insecticides Using LC-MS/MS and Its Application to Japanese Adults. *J Occup Health*. 2014;56(6):461-468. doi:10.1539/joh.14-0077-OA
101. Seccia S, Fidente P, Barbini DA, Morrica P. Multiresidue determination of nicotinoid insecticide residues in drinking water by liquid chromatography with electrospray ionization mass spectrometry. *Anal Chim Acta*. 2005;553(1-2):21-26. doi:10.1016/j.aca.2005.08.006
102. Wei X, Pan Y, Tang Z, et al. Neonicotinoids residues in cow milk and health risks to the Chinese general population. *J Hazard Mater*. 2023;452:131296. doi:10.1016/j.jhazmat.2023.131296
103. Selvam V. Neonicotinoid Poisoning and Management. *Indian Journal of Critical Care Medicine*. 2019;23(S4):0-0. doi:10.5005/jp-journals-10071-23308
104. Tomizawa M, Casida JE. Selective Toxicity of Neonicotinoids Attributable to Specificity of Insect and Mammalian Nicotinic Receptors. *Annu Rev Entomol*. 2003;48(1):339-364. doi:10.1146/annurev.ento.48.091801.112731
105. Morales-Perez CL, Noviello CM, Hibbs RE. X-ray structure of the human  $\alpha 4\beta 2$  nicotinic receptor. *Nature*. 2016;538(7625):411-415. doi:10.1038/nature19785

106. Li P, Ann J, Akk G. Activation and modulation of human  $\alpha 4\beta 2$  nicotinic acetylcholine receptors by the neonicotinoids clothianidin and imidacloprid. *J Neurosci Res*. 2011;89(8):1295-1301. doi:10.1002/jnr.22644
107. McGranahan TM, Patzlaff NE, Grady SR, Heinemann SF, Booker TK.  $\alpha 4\beta 2$  Nicotinic Acetylcholine Receptors on Dopaminergic Neurons Mediate Nicotine Reward and Anxiety Relief. *Journal of Neuroscience*. 2011;31(30):10891-10902. doi:10.1523/JNEUROSCI.0937-11.2011
108. Ramanathan S, Kumar M S, Sanjeevi G, Narayanan B, Kurien AA. Thiamethoxam, a Neonicotinoid Poisoning Causing Acute Kidney Injury via a Novel Mechanism. *Kidney Int Rep*. 2020;5(7):1111-1113. doi:10.1016/j.ekir.2020.04.009
109. Calderón-Segura ME, Gómez-Arroyo S, Villalobos-Pietrini R, et al. Evaluation of Genotoxic and Cytotoxic Effects in Human Peripheral Blood Lymphocytes Exposed *In Vitro* to Neonicotinoid Insecticides News. *J Toxicol*. 2012;2012:1-11. doi:10.1155/2012/612647
110. Krupina K, Goginashvili A, Cleveland DW. Causes and consequences of micronuclei. *Curr Opin Cell Biol*. 2021;70:91-99. doi:10.1016/j.ceb.2021.01.004
111. Cimino AM, Boyles AL, Thayer KA, Perry MJ. Effects of Neonicotinoid Pesticide Exposure on Human Health: A Systematic Review. *Environ Health Perspect*. 2017;125(2):155-162. doi:10.1289/EHP515
112. Mohamed F, Gawarammana I, Robertson TA, et al. Acute Human Self-Poisoning with Imidacloprid Compound: A Neonicotinoid Insecticide. *PLoS One*. 2009;4(4):e5127. doi:10.1371/journal.pone.0005127
113. Phua DH, Lin CC, Wu ML, Deng JF, Yang CC. Neonicotinoid insecticides: an emerging cause of acute pesticide poisoning. *Clin Toxicol*. 2009;47(4):336-341. doi:10.1080/15563650802644533
114. Keil AP, Daniels JL, Hertz-Picciotto I. Autism spectrum disorder, flea and tick medication, and adjustments for exposure misclassification: the CHARGE (Childhood Autism Risks from Genetics and Environment) case-control study. *Environmental Health*. 2014;13(1):3. doi:10.1186/1476-069X-13-3
115. Yang W, Carmichael SL, Roberts EM, et al. Residential Agricultural Pesticide Exposures and Risk of Neural Tube Defects and Orofacial Clefts Among Offspring in the San Joaquin Valley of California. *Am J Epidemiol*. 2014;179(6):740-748. doi:10.1093/aje/kwt324
116. Mutinelli F, Sabatini A, Astuti M. Italian government issues precautionary ban on neonicotinoids. *American Bee Journal*. 2009;149(3):269-270.
117. Food Safety. Neonicotinoids. Food, Farming, Fisheries.
118. Klingelhöfer D, Braun M, Brüggmann D, Groneberg DA. Neonicotinoids: A critical assessment of the global research landscape of the most extensively used insecticide. *Environ Res*. 2022;213:113727. doi:10.1016/j.envres.2022.113727
119. Perry ED, Moschini G. Neonicotinoids in U.S. maize: Insecticide substitution effects and environmental risk. *J Environ Econ Manage*. 2020;102:102320. doi:10.1016/j.jeem.2020.102320

120. Andal F. Neonicotinoids: Bayer's Systematic Risk Mitigation & Portfolio Evolution Towards Minimized Risk for the Environment. In: William-Allee K, ed. Bayer; 2022:1-14.
121. Kundoo A. Role of neonicotinoids in insect pest management: A review . *J Entomol Zool Stud*. 2018;6(1):333-339.
122. Ibrahim MA, Griko N, Junker M, Bulla LA. Bacillus thuringiensis. *Bioeng Bugs*. 2010;1(1):31-50. doi:10.4161/bbug.1.1.10519
123. Hasan F, Mahboob S, Al-Ghanim KA, Al-Misned F, Dhillon MK, Manzoor U. Ecotoxicity of neonicotinoids and diamides on population growth performance of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae). *Ecotoxicol Environ Saf*. 2020;203:110998. doi:10.1016/j.ecoenv.2020.110998
124. Y. Lan, W. C. Hoffmann, B. K. Fritz, D. E. Martin, J. D. Lopez, Jr. Spray Drift Mitigation with Spray Mix Adjuvants. *Appl Eng Agric*. 2008;24(1):5-10. doi:10.13031/2013.24157