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Reservation Policy and Educational Outcomes among Scheduled and Forward Castes in India By Dhiman Roy

Abstract

In India, the lower castes (scheduled castes and scheduled tribes) have historically had lower enrollment rates in schools and institutions of higher education with respect to their percentage share of the total population. Similar to affirmative action in the United States, the reservation policy in India is an active effort by the government to improve education and employment rates to promote better equality, reduce discrimination and enhance social mobility. This paper investigates the effectiveness of the reservation policy in providing educational opportunities to Scheduled Caste (SC) and Scheduled Tribes (ST). We examined trends in school education based on data from the National Sample Survey Organization's (NSSO) household survey. There has been a remarkable increase in gross enrolment rate (GER) both for primary and secondary education between the period 1990-91 and 2011-12 such that there is very little difference between SC, ST and forward castes. The dropout rates for students in class 1-X however remains alarmingly high at 50.3%, 55.3% and 65.9% for forward castes, SC and ST students. The commonest cause for dropout was a lack of interest in studies and not distance from educational institutions or financial constraints. Gross enrolment ratio in higher education for SC and ST students remains dismal at 23.4 and 18 respectively (2019-20). Higher education enrolment rates were correlated to household income. A student from the highest income quintile is six times more likely to enroll in college than a student from the lowest income quintile. The reservation program has proven ineffective at solving the persisting educational disparity of the disadvantaged groups in India.

Introduction

In India, the caste system is a significant social and religious structure initially mentioned in the ancient scripture *Rig Veda*. According to the system, Hindus were classified into four distinct groups: Brahmins, holy priests and educators; Kshatriyas, warriors and kings; Vaishyas, merchants and artisans; Shudras, peasants and laborers; Dalits, who had no caste and were deemed untouchables. The four significant castes were further subdivided into sub-castes based on birth, employment, and marriage. Scheduled castes (SC) and scheduled tribes (ST) have lower

enrollment rates in institutions of higher education than their representation in the general population, as these castes represent communities that have faced historical oppression, inequity, and discrimination (Khan 2022).

Initially created to preserve the social order, the caste system led to significant inequities between castes because of social immobility. Historically, the caste system has significantly impacted the Indian economy (Sekhon 2000; Velassery 2005). Based on their ancestry alone, members of higher castes received enormous opportunities, whereas individuals from lower castes were compelled to take on menial labor for minimal wages (Velassery 2005, 2). Owing to the lack of educational and economic prospects, lower caste members have been unable to transcend their impoverished existence (Munshi 2019). In the decades following India's independence in 1947, there was consolidation in curriculum, professions, revenue, and accessibility of resources across caste groups. While some of this consolidation is caused by reservation policy, caste-based networks may also have contributed to economic equality by capitalizing on opportunities created by globalization (Munshi 2019). Similar to affirmative action in the United States, India's reservation policy [Article 15(4) and Article 16(4) of the Indian constitution] is a concerted effort by the government to increase educational and employment rates to create more equality, minimize prejudice, and increase social mobility. The 93rd Constitutional Amendment and Implementation that came into force in 2006 under Article 15 (clause 5) created special provisions for socially disadvantaged sections, especially the scheduled castes, scheduled tribes and backward castes, to gain admission to educational institutions, (Santhosh Kumar 2008). The reservation system which was designed to combat injustice, inequity, and prejudice that lower caste groups have historically endured primarily aimed to elevate the lower caste population's social and educational levels and enhance their living standards. Casteism was a frequent form of discrimination, of which the SC was the principal target. However, upon independence in 1947, the Indian constitution prohibited this practice. Numerous articles in the Constitution provide educational guarantees for SC and the ST students. Article 15 was revised in 1951 to authorize the State to create specific facilities in educational institutions for the educational reform of SC and ST students. In 1982, it was established that government-aided colleges should reserve 15% and 7% of seats, respectively, for SC and ST candidates (Ferguson et al. 2007).

Higher education which is necessary for individuals to be competitive in the job market is a tool for social and economic mobility. Despite the reservation policy, SC and ST enrollment in universities is still lower than the number of seats designated for these groups. The main causal factors suggested for this are: 1) poor quality education in elementary and secondary schools, 2) limited access to educational institutions owing to rural life, and 3) the necessity for some children to contribute in-home income (Ferguson et al. 2007). Though enrollment in schools shows an impressive increase, the retention of students is a cause for concern.(Tiwari 2012). In this paper, we attempted to analyze the reasons for disparity for the vulnerable population, i.e., SC and ST, both in schools and higher educational institutions.

Methods

This study used data collected by the National Sample Survey Organization (NSSO) to answer our research questions. The data included the 35th round of NSSO's education survey conducted between July 1980 and 1981, and the 71st round NSS survey of 2013/2014 (NSSO 2008,2014), which covered a sample of 1,00,581 households, including both urban and rural households, from India. The data collected for the age group of 3–35 years included their participation in education, dropout rates, and household expenditure.

Research Questions

1. What is the progress in the gross enrollment ratio (GER) of SC, ST, and forward-caste children in India in primary and secondary schools?
2. Why do disadvantaged communities have high school dropout rates?
3. Why is there a gap in university enrollment despite the reservation policy for SC and ST communities?

To answer these questions, we compared the GER and dropout rates for the SC and ST communities with those for forward castes. We also assessed the possible causes of high dropout rates.

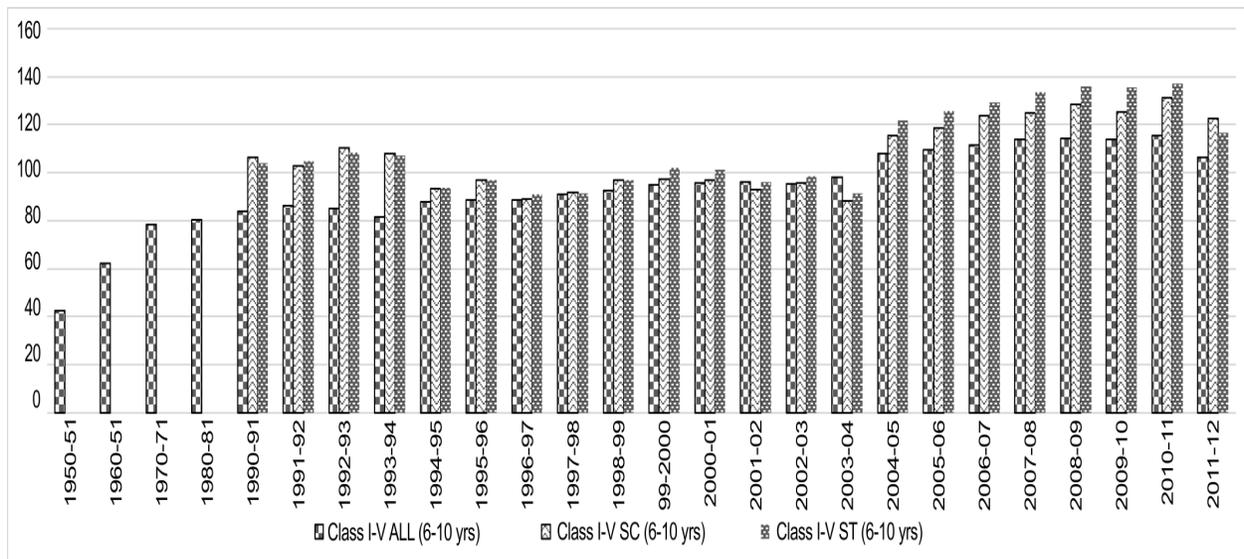
The GER, defined as the number of students enrolled at a given level of education regardless of age, is expressed as a percentage of the official school-age population corresponding to the same level of education. A limitation, however, is that the GER can exceed 100 owing to the inclusion of overaged and underaged students because of early or late entrants

and grade repetition. A dropout is defined as an individual who was enrolled in an educational institution but did not attend the institution or left education.

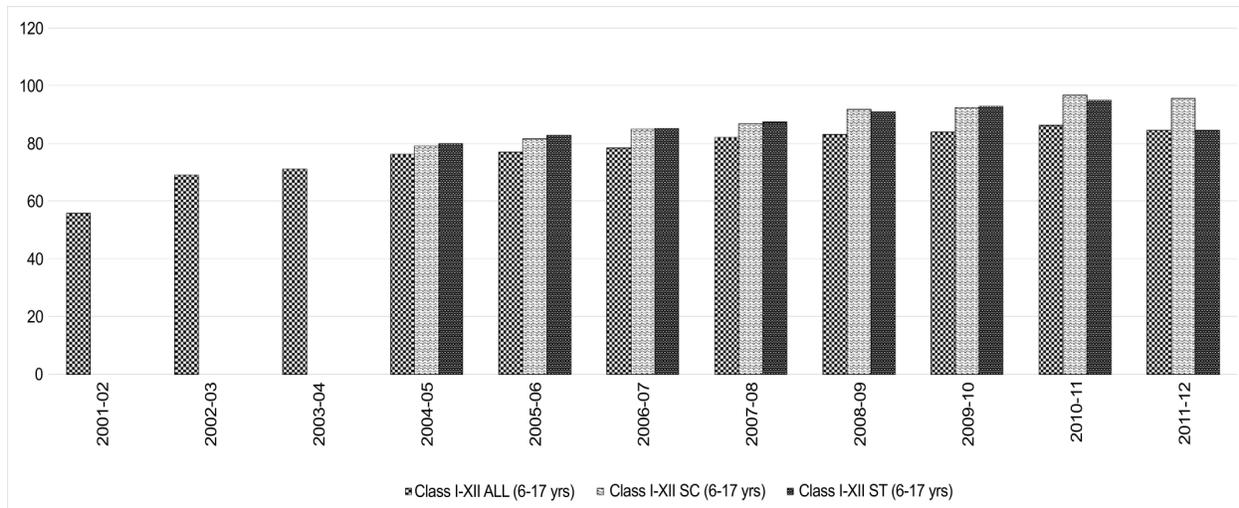
This analysis covered inequalities in access to education (measured as GER or gross attendance ratio) for both schools and higher educational institutions (colleges and universities). We also attempted to identify factors that lead to high dropout rates in schools and poor enrollment in higher educational institutions based on caste, urban/rural location, household expenditure, and so on.

Results

The population percentages of SC and ST have grown from 20.5% in 1951 to 25.2% in 2011 (India 2011). The goal of the Indian government’s policy was to offer education programs to all castes according to their demography. The adult literacy rate (age >16 years) has shown a steady increase over the period of 1961– 2001, from a paltry 8.53%,10.27%, and 24.02% for the SC, ST, and forward castes to 46.34%, 54.34%, and 65.38%, respectively. (Census 1961–2011). The GER for primary school (class 1–V) has steadily increased from 1990–91 for children from the SC and ST communities so that they became on a par with the forward castes (Figure 1a). The GER for secondary school is also similar across all castes in the available dataset from 2004 – 2012 (Figure 1b).



(a)



(b)

Figure 1. (a) Gross enrolment ratio (GER) for primary education (class 1-V)

(b) Gross enrolment ratio (GER) for (class 1-XII)

Although India seems to have made remarkable progress over the past two decades in increasing access to primary and secondary education for vulnerable groups, high dropout rates remain a concern (Figure 2).

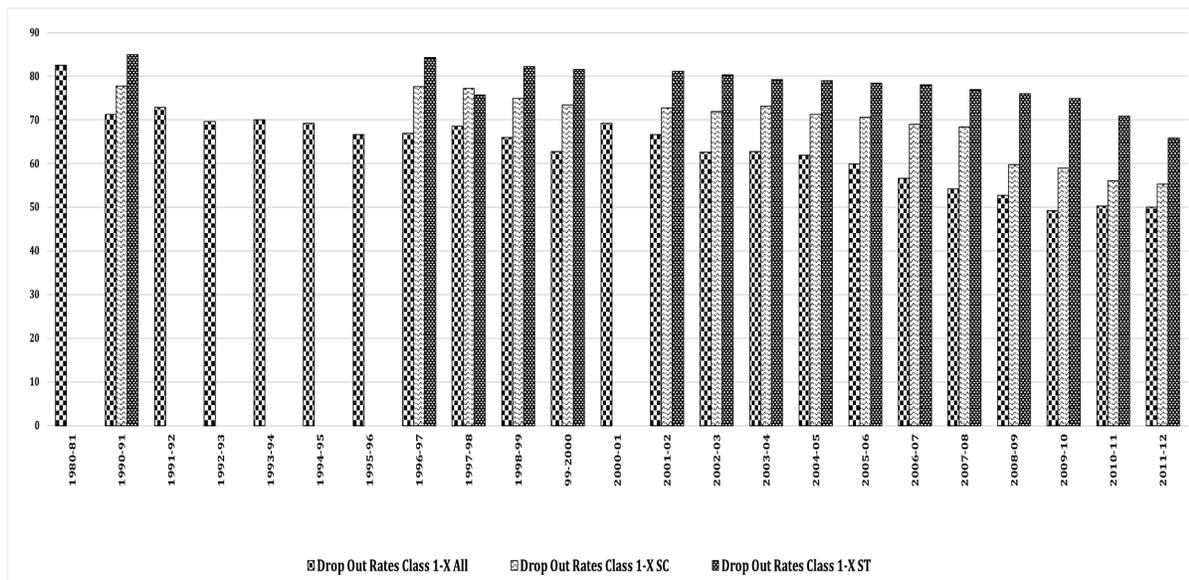


Figure 2. Dropout rates from school (class 1-XII) for all, SC and ST students

The enrollment rate for higher educational institutions, however, shows a gross discrepancy for the vulnerable population based on data from the All India Survey on Higher Education (AISHE) (MHRD 2020).

Table 1. Gross enrollment ratios (GER) in Colleges and Universities for 2015– 2020.

INDIA	2015–16	2016–17	2017–18	2018–19	2019–20
Universities (number)	799	864	903	993	1043
Colleges (number)	39,071	40,026	39,050	39,931	42,343
GER: All	24.5	25.2	25.8	26.3	27.1
GER: SC	19.9	21.1	21.8	23.0	23.4
GER: ST	14.2	15.4	15.9	17.2	18.0

In 2019–20, the GER was 27.1, 23.4, and 18 for the forward castes, SC, and ST, respectively (Table 1).

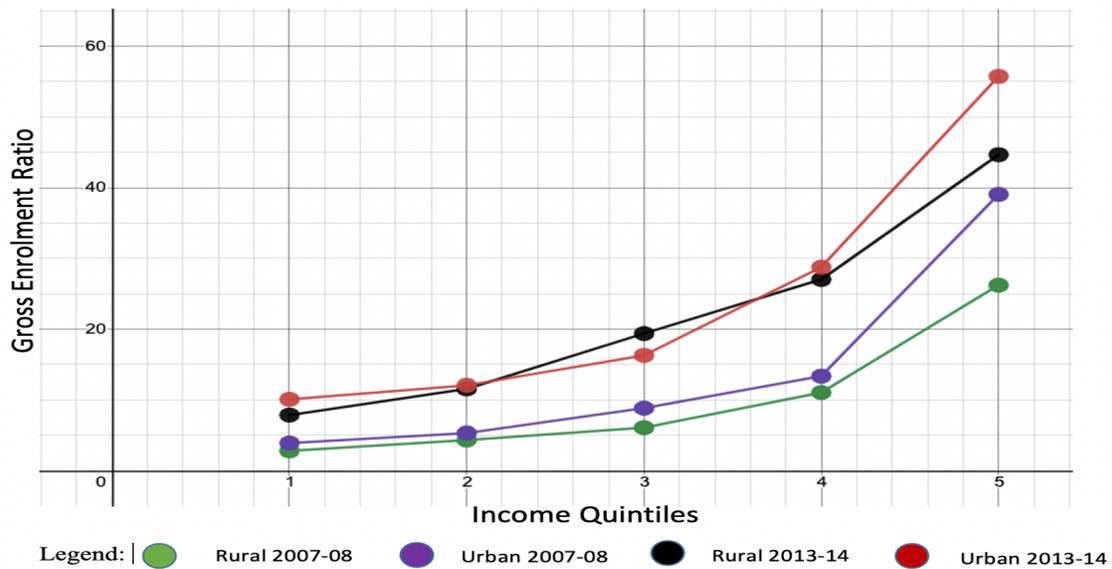


Figure 3. Enrollment rates of urban and rural students in relation to house-hold income .
x -axis: Income quintiles, y-axis: Gross enrolment ratio

Discussion

Social inclusion and higher education are mutually reinforcing. Whenever social inclusion is adopted as a policy in higher education, it has the potential to localize the institution by assisting it in establishing its advantages in local settings. Reservation program in Indian higher education is based on the concept that individuals or groups deprived of social, cultural, or real wealth for centuries owing to the conservatism in the Hindu caste system should be compensated through access to work, politics, and learning (Borooah et al. 2007; Fontaine and Yamada 2014).

The SC and ST castes always had literacy rates lower than those of the national average. Although SC and ST literacy rates rose faster than those of the general population between 1961 and 2001, there were significant variations within the SC and ST castes, depending on rural or urban locations (Chauhan 2008). Notably, the growth in literacy rates for SC and ST can be made especially quickly, since they make up a smaller percentage of the population. Consequently, even nominal advancements result in significant comparative benefits. Owing to their social and geographic isolation, the ST caste is more impoverished than the SC caste. Literacy often results in social advancement and economic development. The significant disparity in literacy rates among the SC, ST, and the general population is significant because of their limited economic and educational possibilities.

Elementary education

In India, **elementary education** is divided into lower primary schools (classes 1–5) and upper primary schools (grades 6–8). In 1990–91, the GER for children with SC was only 80. Remarkably, the elementary GER for the SC and ST castes versus forward castes in 2011–12 was not dissimilar at 122.6, 116.7, and 106.5, as shown in Figure 1a. This demonstrates acceptable development at the primary levels of schooling since the SC and ST castes' enrollment rates are continuously higher than their population rates, which vary between 14% and 16% and 6% to 8%, respectively (Chauhan 2008; Khan 2022).

Secondary education

Secondary education is divided into lower secondary (classes 9 and 10) and upper secondary (classes 11 and 12). For SC and ST castes, The GER for the secondary school is not

dissimilar to the forward castes; however, dropout rates are alarming at 56%, 70.9% and 49.3% respectively (Tiwari 2012). In 2011–12, just 63.3 % of SC students and 61.8% of ST students passed their grade 10 tests) . To encourage more SC and ST students to apply to universities, the Indian government enacted a policy that reserved 15% and 7.5% of all university seats, respectively, for SC and ST students (Ferguson et al. 2007). SC and ST applicants who meet the minimum requirements are eligible for the application.

Reasons for high dropout rates from school

In 1990–91, dropout rates for forward caste, SC, and ST children were 71.3%,77.7% and 67.4%. There has been some improvement in the data from 2011–12 at 50.3%, 55.3%, and 65.9%, respectively; however, these numbers show an alarming trend (Tiwari 2012). A variety of reasons for school dropouts included as stated above, rural location, financial constraints, engagement in economic activity, or school being too far off (Ferguson et al. 2007). The recent National Family Health Survey (NFHS -5), which included a total of 707 districts, 28 states, and 8 union territories with 636,699 households, reported the most common reasons for the school dropout of children at the age group of 6–17 years was that they were not interested in studies (34.6%); the education was too expensive (14.9%), and they needed to contribute to household work 9.5%) (IIPS 2020).

University Enrollment

The SC and ST castes lagged behind the affluent classes in their pursuit of higher education (Table 1). The 22.5% of reserved seats in government universities are seldom filled, with SC and ST castes accounting for only 9.86% and 3.69% of enrollment (MHRD 2020). This is despite the fact that SCs and STs are not underrepresented in elementary education and have a higher enrollment proportion than their demographic share.

Possible factors which explain poor higher education enrollment/Relationship of family income to enrollment:

Regardless of caste, a significant exponential link appears to exist between the GER and family income in rural and urban areas (Figure 3). Poverty has far-reaching consequences on children and may result in lifetime challenges, especially when children do not obtain

comprehensive education (Fontaine et al. 2014, 410). Poverty and education are inextricably linked since individuals living in poverty may forsake schooling to work, which curtails their time for essential reading and numeracy abilities needed to further their careers. Years later, their children find themselves in a similar situation, with little money and fewer options than abandoning their school to undertake employment. Figure 4 shows that the gross attendance ratio for urban students was consistently higher across all quintiles (except for one discordance in 2013–14 in quintile 3). Although overall gross enrollment increased across all quintiles, the disparity between urban and rural enrollment rates has not changed. Rural areas generally have a lower average income. Rural societies are diverse: a small minority consists of wealthy landowners, while the majority consists of laborers with low-skill jobs. Those who live in rural areas in India have fewer opportunities to earn a higher income because of the lack of high-skilled jobs, fewer educational institutions, and poor infrastructure.

A regressive relationship between rural and urban households and the average income per capita can be established. Another obvious relationship is that the average income per capita for SC and ST castes is significantly lower than India's average income per capita. Figure 4 shows the third and final exponential relationship between income and GER. Students in households with higher incomes have a higher enrollment rate owing to many possible factors: they are not affected by India's poor transport infrastructure and can travel long distances with fewer problems; they have access to high-quality books; they need not work for their families' livelihood; they do not have to do household work.

Therefore, SC and ST students have two disadvantages: lower household incomes and rural locations. The majority of SC and ST households live in rural locations, which is addressed in the next section.

Location of SC and ST accommodation

According to the 2011 census, SCs and STs account for only 11.25% of the population in India's six largest cities—New Delhi, Mumbai, Kolkata, Chennai, Hyderabad, and Bengaluru—far less than the country's 25.6% share of SCs and STs. This indicates that most of India's SC and ST populations live in rural areas outside big cities. Only three of these cities had a population percentage of SC/ST of more than 10%: Chennai (17%), Delhi (16%), and Bengaluru (17%) (13 percent). Using Kolkata or Mumbai as examples, the geographic distribution of SC and ST

populations shows that a significant fraction of them live next to railway lines, regions associated with slums, and areas with a lack of access to municipal facilities (INDIA 2011). The census indicates that the bulk of the SC and ST people reside in rural India, while the remainder is split into poverty-stricken districts. For instance, the SC and ST castes are concentrated in the M ward zone, far from the costly real estate of Juhu, Bandra, and Andheri. Thus, poverty and residential segregation may cause a lack of facilities. Irrespective of whether SC or ST families live in urban or rural India, they face various barriers in schools. The discrepancy between rural and urban families' spending on various levels of schooling is large. The annual average household spending on higher education by household location indicates that urban households spend more than rural households, which remains valid for both periods. Urban families spent 1.93 times more on higher education in 2013–14 than in 2007–08. This demonstrates that between 2007–08 and 2013–14, the rural-urban divide in family spending on higher education rose, heavily impacting the learning of rural SC and ST populations the most.

Effect of geographical location on enrollment in universities

Regional differences are more prevalent in area settings than in population, both in colleges and universities. The distribution of colleges and universities is influenced by historical, geographical, and physiographical factors in India's central states. Owing to historical and geographical advantages, the southern area performs better than other regions (Llewellyn 2015; Tom 2019). In terms of geography, constructing infrastructure in mountainous regions (Himachal Pradesh, Uttarakhand, Assam) is more challenging than in plains (Punjab and Haryana) (Vithayathil 2018).

Among India's central states, Haryana ranks first in terms of the geographical distribution of higher education resources and population, followed by Tamil Nadu, Punjab, Karnataka, Uttarakhand, and Kerala. Conversely, backward states such as Odisha, Bihar, Jharkhand, Chhattisgarh, and Assam have a narrow distribution relative to the national average. On average, the southern states of India (Andhra Pradesh, Kerala, Tamil Nadu, and Karnataka) outperformed the northern states (Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Punjab, and Haryana). The eastern states of India (Bihar, Jharkhand, West Bengal, Odisha, and Assam) had the lowest availability of higher education and the GER, followed by the central (Madhya Pradesh and Chhattisgarh) and western states (Gujarat, Rajasthan, and Maharashtra). The

majority of the SC and ST populations live in northern states, such as Bihar, Uttar Pradesh, Odisha, Jharkhand, and Punjab, where fewer higher education institutions are geographically dispersed, resulting in limited access to universities for the SC and ST populations. The distance traveled by a rural student to an educational institution is often substantially more significant than the distance traveled by an urban student. Nearly 12% of secondary school students in rural areas must travel more than 5 km, whereas less than 1% of urban school students must travel the same distance. In rural areas, the average minimum distance traveled by a student was 0.7 kilometers, whereas in urban areas, the average minimum distance traveled by a student was 0.3 kilometers. Apart from the fact that typical rural students must travel more than twice as the average urban students, urban students also have access to superior transportation facilities, such as public transit or better roads.

Poor quality of education

For our purposes, inadequate education is characterized by high dropout rates and low accomplishment scores on standardized tests. Poor educational quality is caused by inadequate educational infrastructure, lack of resources, or ineffective instruction, which may result in pupils being unable to understand the topics taught (Ferguson et al. 2007; Khan 2022; Tom 2019). This affects the overall test results and may even result in student demoralization, resulting in a high dropout rate. India's generally low level of education stems from a lack of school facilities and teacher availability, particularly in rural and geographically less accessible areas. This is undoubtedly a significant factor in the ST population's lower enrollment rate than the SC population. ST communities are often secluded, resulting in limited educational opportunities for young people.

On average, SC and ST families had lower household incomes than the other groups. Additionally, the per capita income of the SC and ST castes was lower than the regional average income. Although inequality across classes and regions is evident since the bulk of the SC and ST population lives predominantly in rural areas, parents must provide education for their children with limited disposable money. This results in substandard secondary education, expanding the divide between the educational standards of the advanced castes and SCs. While there are 83,787 government-aided schools, rural schools receive little support, resulting in inadequate facilities and the hesitation of many instructors to teach in remote areas (Ferguson et

al. 2007). Additionally, owing to the widespread corruption at the governmental level, the bulk of funds earmarked to build rural school facilities never reached their intended recipients. SC and ST students dropped out at a greater rate than did the general population at all stages of the study.

Conclusions

Our analysis of NSSO data to investigate the effectiveness of the Indian reservation policy is as follows:

1. Enrollment of SC/ST students in elementary and secondary schools is comparable to that of the students from advanced castes.
2. Dropout rates for students in class 1–X has shown some improvement when data from 1990–91 to 2011–12 are compared. However, the rates remained alarmingly high at 50.3%, 55.3%, and 65.9% for forward castes, SC, and ST students.
3. We found a significant association between household income and the GER at universities. A student in the highest income quintile is six times more likely to enroll in college than a student in the lowest income quintile. Similarly, students from rural locations are less likely to enroll at higher educational institutions. As the bulk of SC/ST students reside in rural India and have much lower family incomes than the general population, their enrollment rates are low.
4. Despite the reservation policy, GER in higher education for SC and ST students remains low at 23.4 and 18 respectively in comparison to forward castes at 27.1 (2019-20).

Although the reservation policy adopted by the Indian government to address these educational inequities has worked to some extent, its outcomes have been less than optimal.

Policy implications

Although the reservation system is not without criticism, it has addressed the previous lack of access. Higher education in India is still seen as a luxury reserved for the wealthy. Given that the state sponsors most tertiary education in India, higher education provides students with enviable access to multiple financial resources. However, entrance is usually dependent on test scores, and paradoxically, ethnic, economic, and financial hubs have advantages to performing well on tests. Themes such as the death of essential values and the acceptance of transient values and personalities in the national context are critical for developing social inclusion policies. While constitutions provide a legal framework for effective policies for community cohesion,

other government institutions with democratic accountability can interpret and administer them differently. With reservation policies similar to the affirmative action program in the US, there is a need for higher education officials to acknowledge that marginalization occurs and contribute to the government's goal to move away from such a social convention. As political parties and governments change and evolve, reservation policies must evolve to benefit the marginalized. Inclusion criteria, such as family income, limiting benefits to a single generation, or excluding the children of politicians and senior government officials, might help the benefits percolate to a wider section of society.

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The efficacy of Public Service Announcements of Cartoon Network on Mitigating Cyberbullying in Ages of 9-13 By Randhula Wickramasinghe, Sean Formato, Sharissa Khan

Abstract

It is believed that Cyberbullying among children ages 9-13 has reached its climax in modern society alongside the rise in cartoon viewership. This study evaluated the perceived and actual effectiveness of the public service announcements (PSAs) of the Cartoon Network's "Stop Bullying: Speak Up campaign" among children of ages 9-13 in mitigating cyberbullying. Data was obtained from 220 students of grades 5-8. Students filled the surveys based on their viewership on Cartoon Network's PSAs. Questions include "How do you feel about these PSAs?", "Has watching these PSA's stopped you from Cyberbullying?", and "If you were to experience a situation where another person was being cyber bullied, what is your reaction?" The results showcased that the actual effectiveness preceded the perceived effectiveness of PSAs. Although students believed that the message of a PSA resonated with them and affected them, their behavior in actuality remained the same. Future research could identify the aspects of what makes these PSAs effective or ineffective.

Introduction

From a young age, children are exposed to the world of cartoons and animation. Since the establishment of programmes such as Cartoon Network (CN) in 1992, the growth of cartoons has become exponential. Alongside cartoons, public service announcements(PSAs) have also become a prominent aspect of this broadcasting channel. This is evident through various PSAs that have been broadcasted from the 90's . Examples of this include a 2000's PSA of cartoons such as Sailor Moon advocating skin care and the usage of the PSA of "Cartoon All Star to the rescue", in which various cartoon characters come forth to speak out against the usage of drugs. Public service announcements are "creative and informative videos designed to bring attention to a problem relevant to a certain audience, and make a memorable point about it" (Hinduja). As of 2020, Cartoon Network's PSAs shifted their attention from skincare and drug safety towards a new campaign which is called "Stop Bullying: Speak Up" (Florida Atlantic University). This campaign focuses heavily on the impact of cyberbullying.

The first studies on bullying date back to the 1970s, but the theme was popularized mainly from the 1990s, thanks to the continued efforts of [the Swedish-Norwegian psychologist] Dan Olweus (Menin). According to Olweus, bullying comprises of three points: “(a) It is aggressive behavior or intentional harm doing (b) which is carried out ‘repeatedly and over time’ (c) in an interpersonal relationship characterized by an ‘imbalance of power’ ”(Olweus). Cyberbullying is bullying that “takes place over digital devices like cell phones, computers, and tablets. It can occur through SMS, text, and apps, or online in social media forums, or gaming where people can view, participate in, or share content” (U.S. Department of Health and Human Services). Cartoon Network launched the “Stop Bullying: Speak Up” campaign in order to mitigate cyber bullying in children from the ages of 9-12. CN does so by releasing various PSAs which include several cartoon network icons such as, The crystal gems from Steven Universe, The Teen Titans and Gumball.

Previous research indicates that cyberbullying is prevalent in this age group of 9-12, as stated below. In October of 2020, the prototypal nationally representative survey focused on situations of cyberbullying among the ages 9-12 was released by Cartoon Network and the Cyberbullying Research Center. The research study, released as part of Cartoon Network’s highly valued Stop Bullying: Speak Up initiative, found that “one in five tweens have experienced cyberbullying in some way: either by witnessing cyberbullying, having been cyberbullied themselves, or by cyberbullying others” (Florida Atlantic University).

Research Gap

The pre-existing research connects the public service announcements to the “Stop Bullying Speak Up” campaign. However, the pre-existing research does not specify if the PSAs of Cartoon Network are truly mitigating cyberbullying. Furthermore, children of the ages of 9 to 13 in the region of Nassau County, Long Island of New York were not included in the aforementioned studies. The purpose/ goal of this study is to address these gaps. Even though “others have done research on cyberbullying in youth ages 12-17, [researchers] were not aware of anything that had been done to determine what is happening with tweens” (Berthiaume). Additionally, the region Long Island is known for its cyberbullying tendencies. As per the Long Island Coalition Against Bullying, “65% of students say they or someone they know have been bullied online and 68% of students observe bullying in their middle school” (Long Island

Coalition Against Bullying). Hence it's imminent to examine the effectiveness of PSAs on cyberbullying mitigation. The guiding research question is: To what extent do Cartoon Network's Public Service Announcements influence children of ages of 9-13 in Nassau County-Long Island, NY in mitigating cyberbullying?

Literature Review

Sources have been gathered from a variety of databases. Furthermore, to ensure credibility, all the sources are peer reviewed. Keywords used while researching were: Public Service announcements, Children from 9-13, Cartoons, Effectiveness, Aggression, Social Media, Cyberbullying

The following researchers used diverse methods and have developed varying perspectives regarding the correlation between aggression and watching cartoons. Natasa Ruzic is an associate faculty member at the Faculty of Political Science, University of Montenegro and she believes the spike in violence among the younger generation is the most serious predicament the contemporary society faces. Furthermore, many professionals comply with the notion that responsibility for this scenario is borne by schools, families, and the media. The so-called cybernated generation spends much of its leisure time on the internet and acquires the values sanctioned by the media (Ružić). Cartoons are no exception to the "regular depictions of [jovial] carnage and slaughter that desensitizes the viewer's horror to violence and his/her sympathy for victims" (Ružić). This makes it effortless for viewers to live with violence and that empowers them to behave oppressively (Ružić). In conclusion, the more the viewership of cartoons that depict such violence, the more likely the individual is to become more aggressive.

Researchers Silvern and Wiliamson created a field experiment regarding cartoon violence and aggression in preschool children. This experiment lasted over a period of three days. It involved the "assessment of baseline aggression during dyadic play with a classmate, the viewing of the humorously violent cartoon Road Runner; and the playing of the now classic arcade game Space Invaders, which served as the violent video games. Relative to baseline levels of responding, after watching the comedically violent cartoon, preschool youth demonstrated higher rates of aggressive behavior and lower rates of prosocial behavior" (Silvern and Williamson). Therefore, the results of the experiment are congruent with the research of Natasa Ruzic, conceding that cartoon induced violence in turn creates aggressive preschool youth.

The final topic of discussion belongs to Barabara J. Wilson. Wilson somewhat disagrees with Ruzic and Silvern's findings while she argues the nature of cartoons causes aggression whether it be violent or not based on a research experiment. The study proved that children who watched nonviolent cartoon versions reacted much the same as those who watched the violent version of that cartoon(Wilson). In other words, "they judged violence as being more morally acceptable than did members of the control group. The authors reasoned that action cartoons might be so familiar to children and so typically full of violence that even watching a nonviolent segment from this genre triggers mental models or schemata in children that involve justified violence" (Wilson). In essence, cartoons seemed to have ingrained an "aggressive" behavior on children whether they be violent or not.

The aforementioned pre existing research has concluded; children who watch violent cartoons become more aggressive; it is of the utmost importance to conduct research if children are more inclined to use the newfound aggression into cyberbullying and if PSAs against cyberbullying broadcasted on the same channels of these cartoons have an effect on the age group of 9-13.

The Effectiveness of Public Service Announcements

Researchers below using diverse methods have varying perspectives regarding the effectiveness of PSAs. A study conducted by Martin Fishbein and colleagues evaluated "the relative perceived effectiveness of 30 anti drug public service announcements (PSAs) and assessed the extent to which judgments of effectiveness are related to judgments of realism, amount learned, and positive and negative emotional responses" (Fishbein). The study concluded PSAs that spotlight mainly on "saying no" to marijuana should be aired with caution. New PSAs should "focus on the negative consequences of smoking marijuana and, perhaps more important, on the negative consequences of trying marijuana" (Fishbein). Essentially, the study gives conclusive evidence to disprove the usage of simply condoning the substance as bad, but provide evidence to support that claim. This can be relevant to the study of cyberbullying PSAs because just by stating cyberbullying is bad will not instill effective change as giving evidence to stop bullying.

Meanwhile, researcher Jackson Renee examined "two television environmental public service announcements and aimed to answer three research questions : 1) whether or not PSAs

could enhance knowledge on the topics addressed ; 2) whether or not the PSAs were perceived as effective ; and 3) whether or not the PSAs could affect behavior change. Participants completed a pre-test and post-test in conjunction with viewing the PSAs and completed a one-day follow-up survey measuring free recall of the PSAs” (Renee). Their results demonstrated that regardless of medium, topic or method, perceived message effectiveness causally precedes actual effectiveness—under the assumption that "cognitive and emotional responses to the message occur early in the persuasion process” (Renee). Essentially, Renee Jackson concluded that viewers might believe a PSA has educated them properly, but could not have affected them in actuality. This varies from the research conducted by Fishbein that states in the context of cyberbullying PSAs, the children might agree with the sentiments that cyberbullying is wrong, but might still engage in it anyways. Hence, “perceived effectiveness” does not guarantee the actual effectiveness.

Another conclusive study was conducted by Elizabeth Bigsby and her group of researchers which further evaluated the perceived effectiveness (PE) of persuasive messages from PSAs and provided evidence of a causal link from PE to actual effectiveness (AE) (Bigsby et al). The research group “conducted a conservative test of the PE→AE relationship and found additional evidence that PE precedes AE” (Bigsby et al.). What is important about this study is that it furthers the conclusions made by Renee. Therefore, it gives a better analysis of perceived effectiveness and demonstrates PE was positively and substantially allied with the total intention measure (Bigsby et al.).

Even though the pre existing research above contains qualms on the actual effectiveness of PSAs, the general consensus of Fishbein, Renee, and Bigsby is that PSAs do in fact have a perceived effectiveness. Therefore it is vital to perform research on this finding to identify if Cartoon Network’s PSAs are effective in mitigating cyberbullying among the ages of 9-13.

Social Media And Cyberbullying

The preexisting research in this section highlights the connection of Social Media to cyberbullying. In order to assess the PSAs’ effectiveness in mitigating cyberbullying, it is essential to study the usage of one outlet of cyberbullying: Social Media.

As mentioned in the introduction, one of the pivotal articles that lead to this research topic was written by Sameer Hinduja. Further probing into his research, the following survey

conducted together with Justin Patchin was revealed. Accordingly “Almost 15% of tweens have seen cyberbullying, six percent of tweens have been cyberbullied many times, while another 8.5% were cyberbullied once or twice, [and only a]few tweens admit to cyberbullying others (3.2%). These numbers – while not overwhelming in magnitude – still indicate that a solid proportion of young kids face cruelty and meanness online when they are simply trying to enjoy the benefits of gameplay, interaction with their friends, and the sharing of random and noteworthy moments of their days on social media” (Patchin and Hinduja). Based on this it can be inferred that the process of cyberbullying is prevalent on social media.

To prove the increase in the use of social media in children, Rao Sathyanarayana and her research group provided data on a study which was conducted over a 5 year period in India (Sathyanarayana). The results published in 2015 claim that “81% of the children aged 8 to 16 years are already active on social media. Nearly 77% of these children had a Facebook account before they were 13 years of age. Almost 22% of these children face online abuse” (Sathyanarayana). Therefore, Sathyanarayan’s research data are congruent with Patchin’s and Hinduja’s data.

The final study to be considered is the one researched by the scholarly journal, Internet Research, which describes, assesses and fosters understanding of the role of multi-purpose computer networks such as the Internet. This source challenges the reasoning of Sathyanarayana, Patchin and Hinduja. The source concludes even though some literature has brought to attention a number of psycho-social scenarios associated with social media use, there is a gap in the current understanding of how the social media platforms and users’ activities may bring rise to the negative individual-level ramifications, taking into account the possibility of social desirability bias(Salo). “Social desirability bias refers to the tendency of research subjects to give socially desirable responses instead of choosing responses that are reflective of their true feelings” (Grimm). Prospective research should more extensively embrace research designs methods that utilize data from various sources in order to take into account the potential social desirability bias related to people’s responses and perceptions regarding their own cyberbullying or narcissism. Hence, the researchers advocate heavy use of multimethod research designs and mixed methods and as well as data about users’ actual behavior patterns to minimize the risk of social desirability bias (Salo).

The preexisting research has shown that social media is indeed a potential outlet to cyberbullying. Hence, there is significance in researching the effects of PSAs on cyberbullying by analyzing social media activity. To link the prior research and to accomplish a gap, this study evaluated the extent to which Cartoon Network PSAs are mitigating cyberbullying among the children of ages 9-13.

Design of Study

This study evaluates the effectiveness of Cartoon Network PSA's in preventing cyberbullying among the children of ages 9-13. The goal is to identify if PSA's are truly mitigating cyberbullying and whether PSAs can be used as a precaution taken to prevent cyber bullying. The type of data this method section will generate will be helpful to answer the research question.

A survey (Appendix A) was designed to measure the dependent variable, cyberbullying behaviors of children, while the independent variable was whether they had seen the PSAs. Survey method is defined as "the collection of information from a sample of individuals through their responses to questions" (Check and Schutt). As discussed in the literature review, pre-existing research shows the use of surveys as a method of study to measure the effectiveness of PSAs, but not in the context of cyberbullying among the ages of 9-13. This study is significant because it borrows methods from the literature review but evaluates a novel type of PSA: The Stop Bullying Speak Up Campaign.

Subjects

The subjects for this survey were children from the ages of 9-13 from the region of Nassau County- Long Island, NY. This specific demographic group fulfills the gap mentioned in the literature review. Prospective subjects were gathered from the middle schools in the region and the survey was forwarded to their school emails. These email addresses were received by sending a letter (Appendix B) to the middle schools requesting permission from school officials to carry out the survey. In addition, letters were also sent to elementary schools in the region requesting to forward the survey to parents so that their children of the ages 9-11 may answer the survey.

Research Instruments

A digital survey of ten questions was conducted. Nine were multiple choice and one was a free response question. This made both a qualitative and quantitative analysis of effectiveness of PSAs possible. Field experiments and tests were considered as alternate methods but were dropped as only a limited number of people can participate in a field research experiment and a test limits the respondent's ability to freely answer the topic. A digital survey is more broader in the context of answer choices and can be sent electronically to a larger sample size of the population. In addition, survey research is an effective and justifiable avenue to research that has clear advantages in helping to explore variables(Ponto).The survey in this study was conducted using google forms. This is a free software, part of the web-based Google Docs Editors suite. The choice of this digital application eases distribution of the survey to respondents, the collection and analysis of data in a faster and precise manner than in a written survey. This electronic option also gives the flexibility for respondents to answer the survey in their free time. Using google forms ensures the validity of the results as it eliminates human error.

This research survey was influenced by the works of a technical report developed by the U.S Department of Transportation regarding Dynamic Message Signs (Boyle et al.)

W Safety and Public Service Announcements (PSAs) on Dynamic Message Signs for the Orlando area

The goal of this survey is to understand the value of having safety and public service messages on the dynamic message signs you see on our highways. These messages are used to raise awareness of social and safety issues. This survey is completely voluntary and all responses are anonymous and cannot be connected back to any individual. You can also fill this survey out online at:
<https://catalyst.wv.edu/webq/survey/millerik/207615>



Thank you for taking time to be part of this important study.

Q1 (Check only one): How often do you see PSAs on dynamic message signs while driving?

Never Rarely Sometimes Often Always

Q2 (Check only one): How useful is it to have PSAs on dynamic message signs for drivers?

Not useful Somewhat useful Neutral More useful Very useful

Q3 (Check only one): Do you think PSAs on dynamic message signs are effective compared to other media (radio, billboard, TV)?

Much less effective Less effective Neutral More effective Much more effective

Q4 (Check only one): What does "Ride Safely, Sober, Live free, Ride alive" mean to you?

Drive safely under speed limit
 Don't drink and drive
 Drive as fast as you can
 Watch out for motorcycles
 None of the above/I do not know

Q5 (Check only one): What does "Don't ride impaired" mean to you?

Don't drive drunk
 Don't drive distracted
 Don't drive sleepy/fatigued
 None of the above/I do not know

Q6 (Check only one): What does "Eyes on road, hands on wheel" mean to you?

Drive safely under speed limit
 Stay alert
 Drive as fast as you can
 Don't drive distracted
 None of the above/I do not know

Q7 (Check all that apply): How many of the following PSAs on dynamic message signs have you seen while driving?

Avoid aggressive driving
 An alert driver can avoid a crash
 Buckle up, seat belts save lives
 Click it or ticket
 Construction season is approaching, give 'em a brake
 DUI decide before you drive
 Drive safely, look twice for motorcycles
 No excuses, buckle up
 Buckle up, save lives
 Buckle up, just do it
 Slow down, save a life
 Don't be a distracted driver
 Don't barrel through work zones
 Move over for emergency vehicle, it's the law
 Prevent a tragedy, don't drink and drive
 Report impaired drivers, dial *347
 Report reckless drivers, dial *347
 Keep a safe distance, stay safe
 Slow down & obey the posted speed limit
 Watch for motorcycles, drive safely

Minute alterations to the survey wordings were made to facilitate the new material (e.g. phrases such as “driving safely” were altered to “cyberbullying”). The reason for choosing multiple choice questions for the survey was “to obtain clear succinct answers”(Boyle et al). Furthermore, the survey contained branched questions such as “have you seen these PSAs” for the purpose of using a control group; These were respondents who watched cartoons but hadn’t seen the PSAs. The control group allowed for a clearer understanding of whether PSAs were mitigating cyberbullying. Moreover, information regarding questions with “What cartoons do you watch” and if participants have seen the following PSAs were obtained from the Cartoon Network website “shows” and “Stop Bullying: Speak Up” section (Cartoonnetwork.com).

Questions with digital images of PSAs were added in order to appeal to the age demographic. The final free response question “What are your thoughts about cyberbullying and PSAs” was optional and was provided as a means to gain qualitative data. If there is some common experience or inter-subjectivity, it is simple to enter into qualitative research with respondents (Archer). As mentioned above, the choice of questions in the survey (Appendix A), minimized number of questions and straightforwardness of these questions make this research method replicable. The usage of different questions measuring the same characteristic (mitigation of cyberbullying) was to ensure the survey’s reliability.

Procedures

After the collection of prospective subjects, each participant received an email regarding the completion of the survey if the surveyee was from a middle school (ages 12-13). If the surveyee was of the age of elementary school (9-11), then their parents were sent a form of consent (Appendix C) via email for permission to survey their children. Upon agreement to allow their child to engage in the study, the elementary school subjects were emailed a link to the survey. Participants were asked a few questions regarding cyberbullying and viewership of CN PSAs. Participants generally completed the survey within five minutes and the survey was open for responses from January 21st to February 4th, 2022. Participants were given a written debriefing once their responses had been entered and they were thanked for their contribution. The respondents’ submissions were then stored on the google form application.

To ensure confidentiality, both the consent form for parents and the survey informed respondents that names would not be disclosed and the google form application didn’t require the restriction of an email address to answer the survey and results were kept anonymous. To eliminate ethical issues, approval from the Institutional Review Board (IRB) was obtained for the study design and procedures

Analysis

After the results were obtained from the surveys, the responses were converted to a spreadsheet on the “google sheets” (Appendix D-Raw data spreadsheet) application, which belongs to the same suite as google forms and has the same benefits as google forms as discussed in the methodology section. Next the data was coded for statistical analysis. “Coding of data

refers to the process of transforming collected information or observations to a set of meaningful, cohesive categories. It is a process of summarizing and re-presenting data in order to provide a systematic account of the recorded or observed phenomenon" ("Coding of Data"). The data was coded as the following(Appendix F): 1/ All answer choices with a checkbox in the survey were separated into different columns , 2/ For each option a respondent picked, a "1" was assigned, and 3/ For each option a respondent did not pick, a "0" was assigned. The age of each respondent was separated into rows of Appendix F. It is important to note if a surveyee chose "other" as an option, then a value of 1 was assigned and recorded on a separate document (Appendix E) but was not used in coding of data to analyze results as there was a vast variation in "other" responses.

After the spreadsheet was coded, the new datasheet (Appendix F) was imported to PSPP, "a free software application for analysis of sampled data" (GNU Operating System). The reason for using PSPP was for accuracy ,the ability to "store data and its access to GNU Scientific Library for its mathematical routines" (GNU Operating System). Several descriptive statistics such as the mean and frequency were used to test the hypothesis. The hypothesis,which is contradictory to what was discussed in the literature review, is the following; Public Service Announcements from Cartoon Network influence children to stop cyberbullying. Using the terms discovered in the literature review to answer the hypothesis, perceived effectiveness was tested using the means and actual effectiveness was tested using correlation.

Results

Over sixteen hundred students received the survey. 220 students participated in this survey. Based on a 90% confidence interval and a 6% margin of error, the sample size is 169 students. Therefore this sample size is above the 90% confidence interval and 6% margin of error. Hence, the results of this survey are statistically reliable and significant. Some results were excluded as they didn't meet the requirement of the age category 9-13 years.

Table 1 represents the average perceptions of PSAs based on the question "How do you feel about these commercials/PSAs?" Among the six answer choices, the option "I think these commercials/PSA's are very important" received the highest mean value (0.49). This supports the notion that the PSAs have a perceived effectiveness. Table 2 showcases the mean value of the responses to the survey question "Has watching these PSA's stopped you from Cyberbullying".

The closer the mean/ average value is to 1, which was coded as a yes, the more the students believed PSAs have stopped them from cyberbullying. This supports the notion that the PSAs have a perceived effectiveness and the results are in accordance with the literature review as per the studies of Jackson Renee and Elizabeth Bigsby. Table 3 highlights the average responses for the scenario “If you were to experience a situation where another person was being cyber bullied, what would you do?” The response with the highest average (0.49) is “I would tell an adult.” This showcases that the main purpose of the Stop Bullying Speak Up campaign, communicating to others and spreading awareness, is being fulfilled. The mean helps to describe the central tendency of data which is “the statistical measure that identifies a single value as representative of an entire distribution” (Manikandan).

In table 4, the mean value of the responses to the question “Have you seen any of the following PSA's while watching Cartoon Network?” were correlated with the answer choices from table 3. Table 4 shows that “joining a cyberbullying situation ($r = .036$), being silent and ignoring a cyberbullying situation ($r = .016$), telling an adult ($r = .050$), telling a friend ($r = .040$) and leaving the conversation ($r = .06$)” correlated less with seeing a PSA. Even though a respondent believed a PSAs message resonated with them, their behavior more than likely remained the same. This further substantiates the conformity with the literature review as the studies concluded that perceived effectiveness is preceded by actual effectiveness.

Table 5 shows statistics from the demographic section of the survey. 51% of participants identified as 7th grade students, 38.8% of students identified as 8th graders, and a total of 6.7% of the students were from 5th and 6th grades.

Table 1: Average perceptions of PSAs based on the Question “How do you feel about these commercials/PSAs?”

Statistics	Responses to the Question			
	Overrated	Important	Forgotten	Motivational
<ul style="list-style-type: none"> • # of Valid responses • # Missing responses 	105 91	104 92	103 93	106 90
Mean	0.11	0.49	0.36	0.19
Standard Deviation	0.32	0.50	0.48	0.39

Table 2: The Mean value of responses to the question “Has watching these Cartoons Stopped you from Cyber bullying?”

	Has watching these Cartoons Stopped you from Cyber bullying
# of Valid Responses	103
# of Invalid Responses	93
Mean	0.64

Table 3: The Mean value of responses to the question “If you were to experience a situation where another person was being cyber bullied what would you do”

	Join cyber bullying	Stay silent and not join cyber bullying	Tell an adult	Tell another friend	Leave that media platform	None of them
#of Valid responses	189	185	189	189	188	189
#of invalid responses	7	11	7	7	8	7
Mean	0.04	0.22	0.49	0.25	0.37	0.03

Table 4: Correlation between the questions “Have you seen any of the following PSAs* while watching Cartoon Network?” and “If you were to experience a situation where another person was being cyber bullied what would you do”

		Join cyber bullying	Stay silent and not join cyber bullying	Tell an adult	Tell another friend	Leave that media platform
Seen PSAs*	Pearson Correlation	0.036	0.016	0.050	0.040	0.06
	Sig. (2-tailed)	0.623	0.833	0.495	0.583	0.363
	#of valid responses	189	189	189	189	188

Table 5: Frequency of demographics

Grade	Frequency	Percent
5	7	3.6%
6	6	3.1%
7	100	51.0%
8	76	38.8%
Invalid responses		3.6%
Total	196	100%

Qualitative Results

To analyze trends, differences and similarities, the free response questions were transcribed (Appendix G) and then coded for each rising theme. Qualitative coding of free response questions, in an open coding format, was performed with the use of Miles and Huberman's (1994) iterative coding pathway. After repetitive open-coding, 6 final themes appeared (Appendix G) with the following three being ubiquitous: 1) cyberbullying is prevented or mitigated through Public Service Announcements; 2) anti-cyberbullying is seen as a joke and is not effective and 3) age factors

Cyberbullying is prevented or mitigated through Public Service announcements

When asked to state the relationship between the Stop Bullying Speak Up campaign and cyberbullying, many respondents highlighted the impact the PSAs have on mitigating cyberbullying (Appendix G). Participant H stated “I think because the [PSAs] have certain characters, the cartoon-y talk, and acts in it, kids will watch through the whole thing and listen. That's important because... it will be in the back of their head subconsciously helping them”. According to participant U, “ if popular shows show the meaning behind cyberbullying and why it's bad, it will encourage children who watch [the PSAs] to not cyberbully and to be good people going on forth.” Participant AY mentions “As a person who doesn't watch too many cartoons, I was surprised to see this for the first time. I think this type of way of helping to stop cyber bullying could be more effective for some people.” As Jackson and Renee concluded in the literature review, PSAs are noted to have perceived effectiveness on its audience and that it is showcased here.

Anti-cyberbullying is seen as a joke and is not effective

Alongside the comments of how PSAs help stop cyberbullying, many respondents also believed that anti- cyberbullying PSAs are seen as a joke. As stated by participant K, “[PSAs] make cyber bullying look like a joke and it doesn't really help. People think when they see the cartoon that “haha look at this, I'm not even going to listen to it” or sometimes they ignore it and they don't care about it.” Additionally, participant AE mentions “[PSAs] fit into the cheerful colorful aesthetic of cartoon network but they're not doing as much as they could and might come off as ‘cringe’ as a lot of things [tend] to do [for] some people if they are put into tv

shows”. Finally, participant AN believes “ [PSAs] don't help much because cartoons often use slapstick humor, and pretty much borderline bullying, so putting up an anti-bullying PSA isn't going to undo that”. Even though these responses go against the findings of Jackson and Bigsby which state that public service announcements have a perceived effectiveness, they tie back to the notion of Natasa Ruzic. Ruzic believed that the jovial depictions of violence in cartoons is what causes aggression induced cyberbullying and that is being referenced in these responses.

Age Factors hinder the PSAs' effectiveness

Another prominent theme that emerged was age factors. Several respondents expressed their concern with the fact that from the age category cartoon network was trying to appeal to, which was 9-13, was too broad as kids of ages 12-13 rarely watched any cartoons. For example, participant Z stated, “at least half of the kids in the target age range... don't really watch Cartoon Network anymore, unless they're exposed to it by a younger sibling. I don't think many of these kids, at least from 12-13, are exposed to these PSAs, so it doesn't really affect their views on cyberbullying”. In addition, participant P recalled “I really don't think it's helping much especially for older kids who are maybe 11 or 12”. In conclusion, the children of the age range that Cartoon Network was trying to reach out to had already stopped watching cartoons.

Discussion

Overall, the results of this study negated the hypothesis of this study -PSAs influence children to mitigate cyberbullying. Despite the fact that results are in congruence with the literature review, the hypothesis of this study was proven false. Areas of improvement for this study could lie in the fact that the respondents did not see the PSAs in real time but rather were asked had they seen the PSAs before. The results for that question was a nearly even split of the respondents. Therefore, the results may have been different had the respondents been shown the PSAs in real time. Additionally, the survey population should have been increased to further qualify results.

Consummation of Gaps in the Research

This research paper highlights numerous gaps in the pre-existing literature. First, the targeted subjects: children of ages 9-13 were not included in the aforementioned studies.

Secondly, the pre-existing literature has reiterated the link between cartoon violence and the increase in cyberbullying, but not one study mentioned the importance of identifying the effectiveness in mitigating cyberbullying via a PSA. Finally it is important to note that no study has studied the effects of PSAs in the Nassau County-Long Island region of NY. These gaps served as the baseline for this study and were fulfilled.

Implications

By taking this survey, respondents became more aware of the detrimental impacts of cyber bullying. Those that were not previously aware of the connection of cartoon violence induced cyberbullying and the purpose of the PSAs now fully understand the impact. As stated by participant Q, “PSAs did help me stop making negative comments at someone else. You really don't think about making fun of people. You see something in cartoons and you feel like mimicking. PSAs actually help in that way to stop bullying” (Appendix G). Additionally, the results of this paper can potentially be shared with Cartoon Network so that they may refocus their PSAs to solve the issue of cyberbullying. The pre-existing research also indicates the prevalence of cartoon violence induced cyberbullying is increasing (Ruzic). Therefore, other children’s broadcasting channels can take initiative to use their own cavalcade of original characters and create more PSAs to mitigate cyberbullying.

Limitations

One major drawback of this study is the age distribution of the survey questionnaire. While the study was constricted to a specific age group of 9-13, a majority of the population that answered the survey were from the age group 12-13. This uneven distribution could have skewed the results into a biased representation of the population which in turn prohibited from conducting a t-test and obtaining a p-value because of the sample not being representative of the population. The reason for this unbalanced sample is due to the fact that two elementary schools the surveys were sent to did not respond back. A second attempt was made for them to provide children’s email addresses, but no response was returned. Had these institutions provided the survey to their children, the demographic distribution would have been even and the results would not have been skewed. Another limitation is the social desirability bias which has affected the results of this paper. As discussed in the literature review, social desirability bias is “the

tendency of research subjects to give socially desirable responses instead of choosing responses that are reflective of their true feelings” (Grimm). The respondents could have answered questions pertaining to cyberbullying so that they may be viewed in a better light than answering truthfully. Lastly, it is important to note that out of the total number of PSAs created from the campaign, only six were used in this study for the purpose of simplifying the questioning process of the respondent. However, it is uncertain if more PSAs would have captured more varied results.

Future Research Development

This study’s limitations are a stimulus to neoteric areas of research. The pool of subjects can be expanded to better include the age group of 9-11. Furthermore, the area of study could be increased to include more regions of America and reach international heights. Based on the reactions of the respondents to PSAs, studies on the aspects of what makes these PSAs effective can be conducted. For example, future research could identify which characters from cartoons were the most effective in spreading the message, etc. A field experiment could also be conducted where the PSAs can be viewed real time and then the viewers behavior can be studied.

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Evaluating the Most Effective Method of Using Machine Learning to Predict Systemic Crises in Africa by Alexander Hu

Abstract

This paper aims to find and evaluate different machine learning algorithms in order to find the most effective way to predict systemic crises in Africa based on factors associated with these crises. A systemic crises dataset on Kaggle was cleaned and standardized to get it ready for machine learning algorithms. A number of machine learning models were then trained on the data. Cross validation and hyperparameter tuning were used to test and improve the model. Finally, precision, recall, and f1 score were calculated to evaluate the models' performance.

Introduction

In third world countries such as the ones in Africa, systemic crises have historically devastated entire populations of people. A systemic crisis is a systematic disruption in the financial system of a country that has extreme negative effects on the economy of a country. A number of different features are associated with these crises. These features can be utilized with machine learning algorithms in order to determine if a systemic crisis had happened in a particular year or to predict their future occurrence.

Key Terms

1. Systemic Crisis - systematic disruption in the financial system of a country that has extreme negative effects on the economy of a country
2. Standardization - Adjusting a certain data parameter so that it is weighted equally with other parameters
3. Overfitting - When a machine learning model is fitted too closely to the training data, greatly hurting its performance on unseen data
4. Regularization - A method used in machine learning to ensure its adaptability to new data, reducing overfitting
5. Hyperparameters - parameters inputted by the programmer when creating a machine learning model

Data Acquisition

The first step to using machine learning to predict a systemic crisis is to find and manipulate a suitable dataset. For this study, a dataset was found on Kaggle that included information on several countries throughout several years. This dataset had 1059 data samples and included the following columns:

- A case number corresponding to a certain country
- A 3 letter CC3 code corresponding to a certain country
- The country name
- The year
- A binary value indicating if a systemic crisis occurred(1 indicating that a crisis occurred and 0 indicating that a crisis did not occur)
- The exchange rate of that country's currency for USD
- A binary value indicating if a domestic debt default occurred
- A binary value indicating if a sovereign debt default occurred
- The weighted GDP of the country
- The annual CPI inflation
- A binary value indicating if the country is independent
- A binary value indicating if a currency crises has occurred
- A binary value indicating if an inflation crisis has occurred,
- Binary information on whether a banking crisis has occurred in the form of either 'crisis' or 'no_crisis'.

Data Engineering

In order to get this data ready for machine learning, pandas, a python library, was used. Since the algorithm should be able to be applied to any country, the 'case', 'CC3', and 'country' columns were dropped. Since the data included both data on the annual cpi inflation and binary data indicating if an inflation crisis occurred, the 'inflation_annual_cpi' column was dropped due to it being repetitive. Next, since all data must be numeric, the data in the 'banking crisis' column was converted from 'crisis' and 'no_crisis' into 1 and 0. To make sure the 'year' column was not weighted too high, the minimum year in the column was found and subtracted from each value in the column. To make sure the 'exch_usd' column is weighted equally with the rest of the

features, it must be standardized. To do this, the column was first capped at 500. Then, the mean of the column and standard deviation of each value were found. The z-score of each value was then found by subtracting each value by the mean of the column and dividing by the standard deviation. Each value in the ‘exch_usd’ column was set to its z-score. A portion of the resulting data is shown below:

systemic_crisis	year	exch_usd	domestic_debt_in_default	sovereign_external_debt_default	gdp_weighted_default	independence	currency_crises	inflation_crises	banking_crisis
0	102	-0.3974711019	0	0	0	0	0	0	0
0	152	-0.3486347112	0	0	0	1	0	0	0
0	109	-0.392536804	0	0	0	1	0	0	0
0	97	-0.3974711019	0	0	0	0	0	0	0
0	132	-0.3974711019	0	0	0	1	0	1	0
0	57	-0.395479828	0	0	0	1	0	0	0
0	117	-0.3220607966	0	0	0	1	0	0	0
0	95	-0.363477585	0	0	0	0	0	0	0
0	101	-0.3934857074	0	0	0	1	0	0	0
0	55	-0.3955163608	0	0	0	1	0	0	0
0	124	-0.3898013359	0	0	0	1	0	1	0
0	99	-0.350889432	0	0	0	0	0	0	0
0	76	-0.3955657038	0	0	0	1	0	0	0
0	105	-0.3523304367	0	0	0	1	0	0	0

Machine Learning Preparation

With the data cleaned, it was shuffled and split into a training set and a test set. The algorithms will be trained on the training set, and tested to see how well they perform on the test set. Three algorithms were trained and tested on the data.

Cross Validation

To make sure that the hyperparameters found would work well on unseen data and not just the data it is trained on, cross validation was applied. The process of cross validation splits the training set into a smaller training set and a validation set. The model then trains the model on the smaller training set and estimates its performance on unseen data using the validation set. To improve the effectiveness of cross validation, K-fold validation with 5 folds was used. This means that the training set was split and cross validated 5 times, each time with a different validation set, and calculates 5 scores representing how well the model predicted the validation set. The hyperparameters that had the best average cross validation score are the ones that are best to use with the model.

Models

1. Decision Tree Classifier

A decision tree classifier is a machine learning algorithm that creates a tree to classify data. Each element of the dataset is run through the decision tree. At each node of the tree, a parameter of each element is tested and branched off. For example, a node would test the 'banking_crisis' parameter of an element. If it is 0, then it would branch left. If it is 1, then it would branch right. When a leaf of the tree is reached, that would be the result, which would be either a 0 or a 1.

2. Random Forest Classifier

A random forest classifier is a machine learning model that creates and fits a large number of decision trees to a dataset. An average of the results is found to classify an element. If the result is below 0.5, the element will be classified as a 0. Otherwise, it will be classified as a 1. This helps prevent overfitting.

3. Logistic Regression

Logistic regression is a machine learning model that fits a sigmoid activation function to a dataset. Everything on one side of the curve of the function is classified as a 0, and everything on the other side is classified as a 1. A set of weights, one for each feature, is created. Next, a cost function that represents the error between the predicted classifications and the actual classifications is calculated. A process called gradient descent then uses the slope of the cost function to minimize the cost, or error, of the model through adjusting the weights. Once it is minimized, the resulting weights are used with the sigmoid function to compute a vector of values between 0 and 1, with each element representing the result of an element in the dataset. If it is below 0.5, the element is classified as a 0. Otherwise, if it is between 0.5 and 1, it is classified as a 1.

Model Optimization

Using libraries from Scikit Learn, these three algorithms were trained on the data. Hyperparameter tuning was used with cross validation on the data to maximize their performance. Each machine learning algorithm has hyperparameters that can be defined to improve the performance of the algorithm and tailor it to a specific dataset. This means that it is essential to find and use the optimal hyperparameters to increase the effectiveness of the algorithms. To do this, GridSearchCV was used to perform exhaustive hyperparameter tuning. This means that a series of possible values for each hyperparameter is defined, and every possible combination of those values of hyperparameters is tested.

1. *Decision Tree Classifier*: For decision trees, the following hyperparameters were tested:
 - a. 'min_samples_split', which defines the minimum number of data samples required to split an internal node, was tuned by testing the possible values of 2, 5, and 10.
 - b. 'min_samples_leaf', the minimum number of data samples required for a leaf node for 'min_samples_split', was tuned by testing the possible values of 1-10.
2. *Random forests*: For random forests, the following hyperparameters were tested:
 - a. 'n_estimators', which defined how many decision trees, was tuned by testing the possible values of 100, 200, and 300 for 'n_estimators' and
 - b. 'Min_samples_leaf', which defined the minimum number of data samples required for a leaf node, was tuned by testing the possible values of 1-5.
3. *Logistic Regression*: For logistic regression, the following hyperparameters were tested:
 - a. 'C', a value that affects the regularization applied to the algorithm, was tuned by testing the possible values of 0.01, 0.1, 1, and 10.
 - b. 'max_iter', a value that specifies how many iterations of logistic regression should be allowed to run before the algorithm determines that it cannot converge, was tuned by testing the possible values of 500, 1000, and 1500.

Experiments

With the decision tree classifier, random forest classifier, and logistic regression models trained and tuned, their performance on the test set can be evaluated to see which model best predicts systemic crises. The test set was set aside and completely unused in the training and tuning of the algorithms, which means that the algorithms' performance on it can display how well the algorithms work on new data.

To best test each algorithm's performance, a confusion matrix was calculated for each model. This matrix contains four key pieces of data:

- True positives(TP) represent how many times the algorithm predicted that there was a systemic crisis in the test data and there actually was one.
- True negatives(TN) represent how many times the algorithm predicted that there was no systemic crisis and there actually was none.

- False positives(FP) represent how many times the algorithm predicted that there was a systemic crisis when there actually was not one.
- False negatives(FN) represent how many times the algorithm predicted that there was not a systemic crisis when there actually was one.

Based on the confusion matrix, four metrics can be computed that measure how well a model performed. These metrics are accuracy, precision, recall, and f1 score. Accuracy is the number of predictions that were correct out of the total predictions, or $(TP+TN)/(\text{total predictions})$. Precision is the number of true positives out of the total number of predictions that were positive. In other words, it is $TP/(TP+FP)$. Recall is the number of true positives out of the number of total positives. In other words, $TP/(TP+FN)$. F1 score is a metric that takes both precision and recall into account to find a balance between them. This is calculated through the equation $(2*\text{precision}*\text{recall})/(\text{precision}+\text{recall})$. These metrics are all between 0 and 1. The closer they are to 1, the better the model performs.

The confusion matrices and performance metrics of each of the three machine learning models are shown below:

Decision Tree

		Predicted classification	
		Positive	Negative
Actual classification	Positive	TP 15	FN 2
	Negative	FP 1	TN 194

Accuracy: 0.9858
Precision: 0.9375
Recall: 0.8824
F1 Score: 0.9090

Random Forest

		Predicted classification	
		Positive	Negative
Actual classification	Positive	TP 16	FN 1
	Negative	FP 1	TN 194

Accuracy: 0.9906
Precision: 0.9412
Recall: 0.9412
F1 Score: 0.9412

Logistic Regression

		Predicted classification	
		Positive	Negative
Actual classification	Positive	TP 12	FN 5
	Negative	FP 2	TN 193

Accuracy: 0.9670
Precision: 0.8571
Recall: 0.7059
F1 Score: 0.7742

Conclusion

In this study, we found the most effective method of using machine learning to predict systemic crises in African countries. An African systemic crises dataset was found on Kaggle and cleaned using the python pandas library. Three machine learning models were then trained on the dataset. Hyperparameter tuning was used in these models along with cross validation in order to ensure the models would adapt to unseen data. Finally, the accuracy, precision, recall, and f1 score of the algorithms was calculated.

Out of the three models trained, the random forest classifier had the highest accuracy, precision, recall, and f1 score. This makes it the clear best model for predicting systemic crises in Africa using this dataset. Out of a total of 212 predictions made in the test set, it predicted 16

true positives, 194 true negatives, 1 false positive, and 1 false negative, giving it an accuracy of 0.9906 and a precision, recall, and f1 score of 0.9412.

Overall, this paper yields an effective way to predict systemic crises in Africa based on certain factors. However, more research could be done into how other factors could cause systemic crises, and data could be collected on those. This would improve the flexibility of the machine learning algorithm and make it apply to even more situations.

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The Emergence of Quantum Advantage and Predictions of Its Limiting Factors By Siddharth R. Chander

Abstract

One reason why the interest in quantum computers has spiked recently is quantum advantage, or when a quantum computer can outperform a classical computer. Quantum advantage arises from the unique properties of quantum systems, which allows a quantum computer to outperform current, well-developed classical computers. Google recently claimed the first experimental demonstration of quantum advantage in 2019, performing a calculation in 200 seconds that would have taken the then-fastest classical supercomputer 10000 years (revised to 2.5 days based on research from IBM in 2019). Since then, different groups have claimed quantum advantage through other quantum systems. We will look into Google's experiments and understand how they made their claim of achieving quantum advantage. After that, we will analyze two factors that are vital aspects of quantum hardware and can help in cementing quantum advantage. Finally, we make predictions concerning two critical quantum hardware limitations. Note that this paper assumes you understand some linear algebra and fundamental physics.

Keywords: quantum advantage, quantum supremacy, quantum error correction, superposition, entanglement, decoherence, quantum error rates, fidelity

Quantum Computers and the Emergence Of Quantum Advantage

In the 20th century, classical computers revolutionized many aspects of our lives, especially in solving problems that would have taken impossibly long times otherwise. Now, a new form of computing, quantum computing, is being explored. People call it revolutionary due to its advantages over classical computers in problem cases like data analysis, pattern matching, quantum simulation, and cryptography (Tomas), making them the next step in computing as we reach the limits of classical computers. In this paper, we will begin by going over quantum bits and gates, two fundamental parts of quantum computers. After that, we will look at the unique properties of quantum systems that give them advantages over classical computers: superposition, entanglement, and interference. From there, we will delve into quantum advantage and computational complexity, which is useful for measuring quantum advantage. We will also

cover the primary limitations of quantum computers in their quest to achieve quantum advantage, decoherence and their susceptibility to errors, explaining why advanced quantum algorithms cannot be currently used to achieve quantum supremacy. To tie together these topics, we will discuss Google's 2019 claim of quantum advantage in random circuit sampling. We will also analyze two factors related to the development of quantum hardware and advantage; the number of qubits and error rates of quantum devices. Finally, we will look into the future of quantum advantage, considering how quantum computers are at the threshold of quantum advantage.

Quantum Bits and Quantum Measurement

Quantum bits or qubits are the fundamental building blocks of quantum computers. Crucially, qubits can store a 0, 1, or a combination of 0 and 1, while a classical bit can represent a 0 or 1. The state of a qubit can be a combination of 0 and 1, but when measured, the qubit will “collapse” into only one of the two values (“*What Is a Qubit?*”). The ability for qubits to be in a superposition of the 0 and 1 states allows them to store more information than classical bits. While bits are typically physically implemented using transistors in the on or off position on silicon chips, there are many ways for qubits to be physically represented (no best method currently). Some ways qubits are physically represented are by superconducting (electrical resistance drops to near zero when specific materials called superconductors are cooled to certain temperatures) circuits, trapped ion quantum computers, and photonic (using light instead of circuits) quantum computers. Generally, a qubit physical system is one that behaves like a “two-level” quantum system, similar to how one can model a classical bit with any physical system that has two distinct states. Finally, some ways qubits are physically represented are by superconducting (electrical resistance drops to near zero when specific materials called superconductors are cooled to certain temperatures) circuits, trapped ions, and photonic circuits (using light instead of circuits) (user609).

We mathematically represent qubits using a column vector, with the top component being the contribution of the zero state and the bottom component being the contribution of the one state to the qubit’s overall state (The Qiskit Team). These vectors should then be normalized (become unit vectors). Normalization begins by finding the length of the current vector by taking the square root of the sum of the squares of two vector components ($\sqrt{a^2 + b^2}$). Then, take the

reciprocal of the vector's length and multiply it with the two components of the original vector $(1/\sqrt{a^2 + b^2} * [a \ b])$ (*Vector Magnitude & Normalization (Article)*, n.d.). A normalized vector is needed for Born's Rule, which allows one to find the probabilities or contributions of the zero and one states (at least for a single-qubit state). To find each value, one has to square each normalized term in the vector (Academy). Note that Born's rule and normalization apply to multi-qubit states, but in our example, are just applied to two components.

A fundamental aspect of qubits is quantum measurement, where a quantum system is manipulated to determine its output state. Measured qubits are usually represented as zero or one (Bassani et al., 2005). If the qubit is in a combination of two states, each state will have a probability amplitude, and the qubit will be more likely to be measured (and will collapse) into the state with a higher probability. The primary restriction given by quantum measurement is that once a qubit is measured, it will collapse to one of two basis states (ex. 0 and 1 for z-axis) of the measurement basis (which axis the qubit is being measured relative to). Each axis represents a different basis to perform the measurement for measuring qubits along the X, Y, and Z axes, with the specific basis states of each axis being shown in figure 1. If we measure qubits with the z-axis, they will be in the state of zero or one. If we measure qubits with the x-axis, they will be in the states of plus and minus. The y-axis is the imaginary numbers axis (which allows for the complex portion of quantum states) (*Accurately Measuring Qubit States*, n.d.).

(X)	(Z)	(Y)
$ +\rangle = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$ 0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$	$ +i\rangle = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ +i \end{bmatrix}$
$ -\rangle = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$	$ 1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$	$ -i\rangle = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -i \end{bmatrix}$

Figure 1: Superposition Bases - Vector Representations of the Basis States of Each Measurement Axis. (*Superposition Bases*)

Qubit states are visualized using the Bloch sphere, as seen in figure 2. Qubits are modeled as rays coming from the sphere's center to the surface, between the endpoints of one of the three axes. This positioning allows one to see if the qubit is at one of the basis states and see

whether the qubits have a higher probability of being measured as one of the base states, as indicated by how near the end of the ray is to one of the endpoints of the axis (Nielsen & Chuang). Note that the gamma and mu states in Figure 2 are the basis states of the y-axis, which are also shown in Figure 1 as the two states with imaginary vector components.

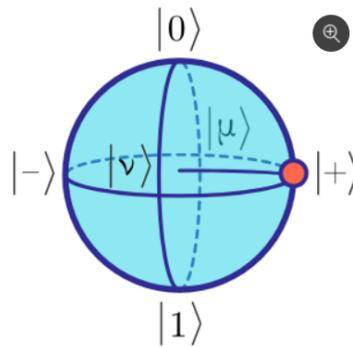


Figure 2: Bloch Sphere - With Some Key States Labeled. *(Brilliant) The Bloch Sphere is used to model any single-qubit state*

Qubits can also be represented using ket notation, as shown in Figure 3. These kets represent a qubit's vector forms, with each ket corresponding to the state of a qubit (C. P. Williams, 2010). The vector components can be any complex number and can be negative, caused by a phase shift, typically not normalized, but are manually normalized (by a person or computer) to perform any needed calculations. Note that a phase shift happens when the wave of the state is at a different point of the wave cycle compared to a wave without a phase shift. These normalized versions of the components (of the overall state) are called probability amplitudes, and if we take their modulus/absolute value squared, we get each state's chance of being measured. With an understanding of qubits, we can move on to quantum gates, which use qubits.

$$|00\rangle = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}, |01\rangle = \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}, |10\rangle = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}, \text{ and } |11\rangle = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

Figure 3: Ket and Vector Notations of Two-Qubit States. *The diagram below shows two-qubit states represented with kets, with the first number in the ket being the state of the second qubit and the second number being the state of the first qubit. The numbers (from top to bottom) show the probability of the 00, 01, 10, and 11 states (“Learn Quantum Computing on Brilliant”).*

Now, we will look into quantum gates, which allow qubits to change and perform operations.

Quantum Gates

Quantum gates change the state of the input qubits based on a defined set of rules and can be represented as matrices. They are combined to create advanced algorithms, which will be essential later in this paper. While some quantum gates have equivalent classical gates, others have no classical analog. There are a near-infinite number of quantum gates, and Bostock provides an excellent introduction to these in [*Programmable Logic Devices: Technology and Applications*] (Bostock). Note that if a qubit is on a different basis (X or Y), then the physical effect of the gate (ex. rotation of qubit) is the same, but the mathematical representation will be different based on the original qubit's basis. For example, the X, Y, and Z gates rotate a qubit 180 degrees about the X, Y, and Z axes of the Bloch sphere (C. P. Williams). The X-gate is equivalent to the classical NOT gate, and the Z-gate (phase flip) changes the phase of the one state. Then, there are multi-qubit gates called controlled gates, which have one qubit that acts as a control for an operation done by the controlled gate to the other qubit(s). One control gate is the control-NOT (CNOT gate), which performs the NOT procedure on the second qubit only if the first qubit is in the ket one state. The general form for a control gate is called a control-U gate, where U represents any single-qubit gate used with the general controlled gate (Nielsen & Chuang). Finally, the Hadamard (H) gate changes from the Z to X basis and back again, representing a change-of-basis operation. Note that the plus and minus states, the superpositions (combinations) of the zero and one states, originate from the H-gate applied to the ket zero and the ket one states respectively. The ket minus state has a “-” symbol between zero and one instead of “+,” indicating a phase shift

There are many other gates, including the three-qubit Toffoli/CCNOT (which requires the first and second qubits to be ket one to swap the state of the third qubit) gates (Djordjevic). With many possible gates, one must consider sets of universal quantum gates, where any possible operation can be done using this set of quantum gates. As there are an uncountable number of quantum gates, one can require that any quantum operation can be approximated by a series of gates from the universal set of quantum gates. First, we can use the T-Gate to model all

single-qubit states. The more T-gates added in a single circuit, the more single-qubit states one can generate. Note that any multi-qubit quantum gate can be represented with one or two-qubit gates only, but three-qubit gates are needed to represent classical gates in quantum systems (Barenco et al., 1995, p. 52). One set of universal quantum gates is the Hadamard, X, CNOT, and T-gates (not Toffoli) (Schmassmann). Still, all these gates (some work better on different quantum hardware) can only aid quantum computers because of their unique properties.

Extra Resources of Quantum vs. Classical

Quantum computers have three fundamental properties that allow them to perform tasks much differently from classical computers, and in some cases, complete tasks faster than any classical computer. These three properties are quantum superposition, entanglement, and interference.

Quantum superposition is when a qubit is either in one of two states or a combination of both states. When measured, the qubit collapses to one of the two states (“*What Is Superposition and Why Is It Important?*”). The benefit of superposition is seen when using a quantum computer to try different paths in an algorithm. Since a qubit in superposition can be in a combination of two states, quantum computers can simultaneously try two logic paths (ex. if-then). This can give a quantum computer an exponential speed-up. Quantum superposition also allows for more information storage because if one qubit is in superposition, then the number of classical bits needed would increase if we want a more accurate representation. This is because bits can be only zero and one, but superposition states have numbers other than zero or one, and those numbers need more than one bit for representation. Moreover, qubits are represented by information-denser complex numbers than integers representing bits. Superposition also allows quantum algorithms to process more information than classical algorithms. Still, when measured, the algorithm’s output would be a classical bitstring (“*Learn Quantum Computing on Brilliant*”). Essentially, superposition allows qubits to process exponentially more information than classical bits, but once measurement occurs, the qubit is reverted to a non-superposition state.

Quantum entanglement is when two particles are connected across any distance, and measuring one particle allows one to determine the second particle's state without another measurement. The primary benefit of entanglement is that information is stored in the system of entangled qubits, rather than just in the individual qubits. Classical computers have correlations

between bits, allowing for one to determine the state of multiple bits by measuring one bit, but entanglement provides more information than correlation. Entanglement allows one to determine the qubit's state, even if both qubits have different states. Note that the control qubit or the qubit being monitored first needs to be in superposition to achieve entanglement. Finally, entanglement (superposition on its own is not enough) is required for a quantum algorithm to achieve an exponential speed-up compared to a classical algorithm (Jozsa & Linden). One needs to apply the Hadamard Gate and CNOT gates, then use the X and/or Z gates to generate one of four maximally entangled states, called the Bell States (Coggins, 2021).

Quantum interference allows for different states to affect each other. This is seen in the Double Slit experiment, where a particle emitted from a source reaches a detector through an upper or lower slit. This experiment shows that a single particle travels through both slits when not being measured. When measured at one of the two slits, interference will cause the probability of the particle entering that slit to be amplified such that the particle will only enter the measured slit. The primary use of interference is to allow a quantum computer to eliminate incorrect solutions without fully calculating them, as seen in Grover's Search Algorithm. In this algorithm, potential solutions to a problem are states with equal probabilities to each other. As this algorithm runs, amplitude amplification occurs. Answers deemed incorrect destructively interfere while the correct answer constructively interferes until, when measured, the output will be the state of the correct solution ("*A Fast Quantum Mechanical Algorithm for Database Search*"). These unique properties of quantum systems allow quantum systems to theoretically solve new problems that are difficult and even impossible for classical systems to solve. Still, there are limitations to current quantum systems holding them back.

Primary Limitations of Quantum Computing - Decoherence and Quantum Errors

Quantum coherence is the ability for a qubit to maintain its state. Also, coherence is key to preserving superposition and entanglement (Zhao et al.). Additionally, coherence is related to the quantum mechanical property in that all objects have wave-like properties (including particles like photons), as seen in the double slit experiment. As the particle travels to both slits and has wave properties, the particle's wave function goes through both slits. Relating everything to coherence, the particles having wave-like properties (allows for interference) are associated with the coherence of the particle's waves passing through the experiment's slits (Baumgratz et

al., 2014). Note that the wave function going through both of the slits demonstrates coherence because while a particle cannot go through both slits, a wave can, and in the case of an object with quantum-mechanical properties, when measured (ex. With detectors at each slit), it will behave like a particle, but if not measured, one can see results that indicate it is a wave.

Quantum decoherence is the loss of quantum coherence. When decoherence happens, quantum devices lose their quantum properties. Decoherence is similar to how classical systems lose energy (transferred out of the system) due to friction (Zeh). Decoherence is the loss of entanglement, superposition, and generally results in a loss of information to an external environment (Penrose). Concerning quantum advantage, quantum decoherence limits our ability to build systems with large numbers of qubits because more qubits add more errors. On the other hand, coherence is one of the reasons quantum advantage has been demonstrated recently in the development of quantum hardware. Additionally, the development of long coherence/high fidelity qubits and gates have begun to provide results. Especially as more qubits are used for calculations, we need methods to correct these errors.

Quantum errors are another significant limitation for quantum computers, especially in their ability to run advanced quantum algorithms. Quantum computers, in their processing of information using qubits, are vulnerable to many errors. One common type is called bit flip, where the states of qubits change suddenly (randomly), resulting in qubits in the state of one losing the information they hold in that state and reverting to the zero state, causing issues in how quantum computers can process data (“Eliminating Errors in Quantum Computing”). Another type is the phase flip error, in which the phase of qubits changes (ex. Phase of one state changes from positive to negative) (Coggins). Quantum error correction works to fix errors in quantum gates, qubits, measurement, and the preparation of quantum systems for usage. A significant restriction to quantum error correction is the no-cloning theorem. Due to this theorem, which states that it is impossible to create an independent and identical copy of an unknown quantum state, one cannot make multiple copies of the same state to protect against errors like in classical error correction (Peres). Finally, methods using multiple current error-prone qubits to model error-free qubits are being considered. For example, a seventeen-qubit model that used nine qubits for data and eight qubits for error correction could fix both bit and phase flip errors for two-qubit operations (Kjaergaard et al.). Basically, seventeen current qubits were needed to

model two error-free qubits. In the end, quantum decoherence and errors are two causes that are limiting quantum hardware from reaching quantum advantage in more cases.

Computational Complexity

Computation complexity measures the number of resources needed to run an algorithm. Usually, a function of $n \rightarrow f(n)$ represents complexity, where n is the size of the input to the algorithm. The function represents the maximum resources needed for all cases with n inputs or the average amount necessary for all cases with n inputs (Dean). Time complexity is expressed as the number of basic operations (each takes the same time on a given device) on a size- n input. Bit complexity refers to the number of operations done to bits or qubits needed to run an algorithm and has similar results to time complexity. Space complexity is the size of the computer memory required to run an algorithm (Arora & Barak). All these forms of complexity and other forms can be represented using “Big-O” notation. This notation, in the form $O(n)$, is used to characterize algorithms based on their growth rate. An example is $O(n^2)$, which means that an algorithm has a quadratic run time, and as the input linearly increases, the complexity increases like a quadratic function (Mohr). With an understanding of computational complexity, we can move on to understanding quantum advantage.

Introduction to Quantum Advantage

Quantum advantage is when quantum computers outperform current classical computers. (Preskill). In general, multiple factors allow quantum computers to achieve quantum advantage. Three main factors are quantum parallelism (previously discussed), quantum entanglement (including quantum superposition), and quantum interference (Djordjevic).

Quantum parallelism allows a single quantum computer to perform multiple calculations simultaneously. In one computational step, a quantum computer can take strings with length N and encode them, allowing the quantum device to follow 2^N classical paths, providing an exponential speed-up (in some cases) compared to classical computers. This rule is one of the main reasons that it is possible to achieve a quantum advantage and used for algorithms like Shor’s Integer Factorization Quantum Algorithm (that could, if used by a suitable quantum computer that we currently do not have, break the RSA Cryptography protocol) and Grover’s search algorithm (Djordjevic). Note that in relation to what quantum computers can do, the RSA

Cryptography protocol works by using two keys, with one of the keys being a long integer that is basically impossible for classical computers to factorize into prime numbers, which would allow for the protocol to be deciphered.

Quantum entanglement aids in allowing quantum computers to achieve a quantum advantage by allowing each entangled qubit to send more information than one classical bit. Suppose the state of one entangled qubit is changed (ex. X, Y, or Z gate is applied) without making changes to the other entangled qubit. In that case, the state of the second qubit will also change, allowing for measurement only on the second qubit to determine the changes on both entangled qubits, allowing for gaining the equivalent information of two classical bits from measuring one (of two) entangled qubit (Preskill). This allows quantum computers to modify one qubit to harness multiple qubits, allowing for quantum advantage. Note that there is no classical analog for quantum entanglement. Quantum interference can result in faster quantum systems by using interference to amplify the solution states. Additionally, quantum interference would reduce the chance of errors, as it would not matter if the errors would happen in the non-solution states. Since amplification does not find the solution's quantum state, the quantum computer can be faster than if it had to find the solution state (Shiekh). Overall, quantum parallelism, quantum entanglement, and quantum interference work to provide a quantum advantage, and their benefits can be measured with concepts from computational complexity. Now, we will move on to Google's 2019 demonstration of quantum advantage.

Sampling Outputs of Random Quantum Circuits (Random Circuit Sampling)

Google claimed to have achieved quantum advantage by running 12-53 qubit quantum circuits, completing them in 200 seconds, and then showing that the current fastest supercomputer would be able to simulate those random circuits in 10000 years. This leads to how Random Circuit Sampling, or the sampling of the probability distributions of randomly selected quantum circuits, is a viable way of demonstrating a quantum advantage. First, Google limited the circuits to around 1,000 gates to create an upper bound on the number of errors their random circuits could have. Then, the circuits would be made using a random set of gates without any pattern. As there was no pattern in these circuits that classical algorithms could use to simulate the circuit rapidly, it would require large amounts of time and resources for classical systems to simulate the random quantum circuits. Each implementation of the random quantum

circuits would create a string of bits, as seen in Figure 4. With quantum interference, the "solution" bit strings are amplified and are more likely to be outputted as these circuits are repeatedly run (Arute et al.). As the number of qubits and the gates increased, it became exponentially harder for classical computers to simulate the circuits, primarily due to the extra information qubits hold compared to bits.

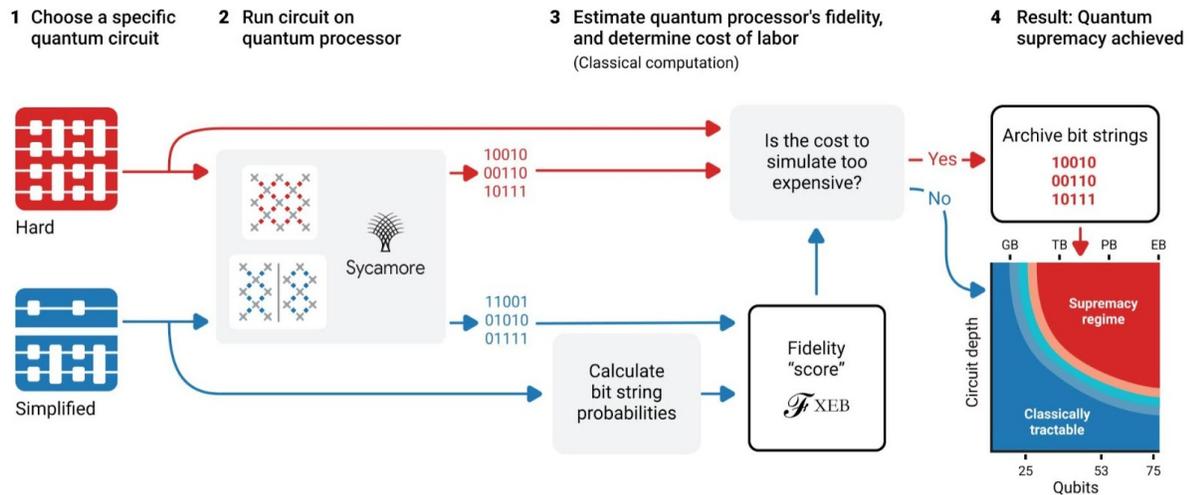


Figure 4: General Steps of Google’s Experimental Procedure. (*Process for Demonstrating Quantum Supremacy.*) The image details how Google conducted its experiments to achieve quantum supremacy.

To achieve quantum supremacy, Google created an algorithm that generated random circuits, as seen in the first step of figure 4. The algorithm first selected a single-qubit gate from the \sqrt{X} , \sqrt{Y} , and $(X + Y)/\sqrt{2}$ gates to be applied to 53 qubits. Then, two-qubit gates were applied to each qubit pair. Each sequence of gates was selected to minimize the length of the circuit needed to create an entangled state. This algorithm allows for a high computational complexity as seen in the large time differences between the run-time of the circuits on the quantum processor compared to the predicted run-time on a classical computer (Arute et al.). Google ran circuits using the same number of gates for each circuit on quantum computers and simulated them on classical computers (Arute et al.) until it was unfeasible to simulate the circuits classically (then making predictions for classical runtime). While classical computers were able to run the circuits that the quantum computer ran, it would have taken the classical

computer thousands of years to simulate the 53-qubit random quantum circuits, as seen in Figure 5 (Arute et al.).

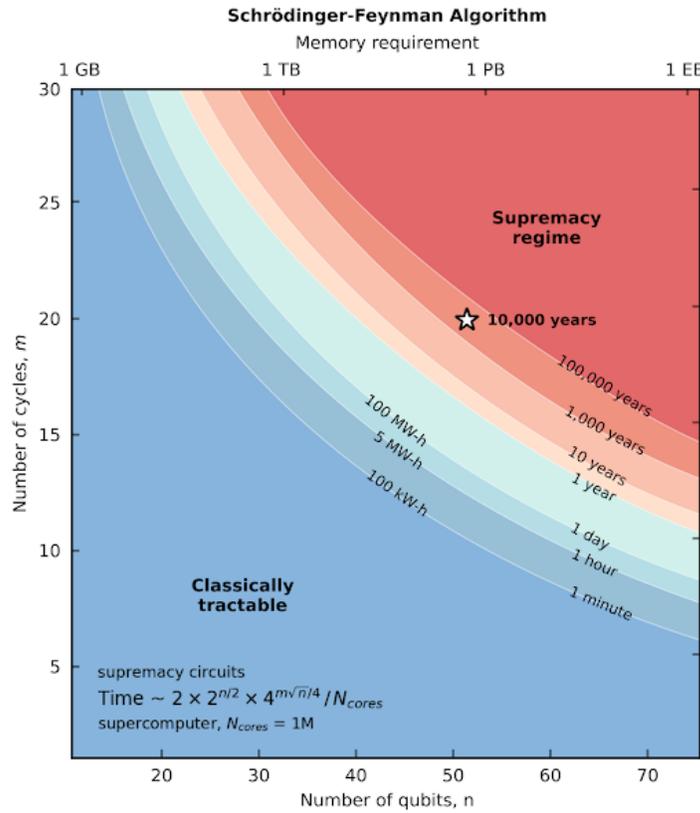


Figure 5: Chart of Google’s Anticipated Time Difference Between Classical and Quantum Computing Techniques. (Martinis & Boixo) The image shows Google’s diagram, accounting for the number of times the quantum circuit is simulated and the number of qubits each circuit had to represent the theoretical time complexity a classical computer would have needed. This image also shows the classical computing memory required to simulate the equivalent quantum circuits.

To demonstrate quantum advantage, Google used its 54-qubit Sycamore quantum processor. Figure 5 shows extrapolations for using more than 54 qubits in addition to the results Google got when using less than 54 qubits. Each qubit in this processor is connected directly to four other qubits, allowing all qubit states to interact rapidly, where each operation between qubits is faster than classical bits, causing the overall processor state not to be simulated

effectively on a classical processor. Additionally, Google improved quantum parallelism with two-qubit gates using a control knob that could turn off qubits, reducing errors by reducing and adding qubits when needed. Moreover, as neighboring qubits could be turned off, this reduced errors from spreading between connected qubits and prevented the information from neighboring qubits from mixing. Overall, the primary reason why Sycamore was able to achieve quantum advantage was with its linking of qubits, which allowed for a reduction in quantum errors, but not in the reduction of usable qubits for calculations (instead of just for error correction) (Arute et al.).

While Google used a quantum algorithm that reduced the computational complexity for their quantum device while increasing the computational complexity for a classical device, Google estimated the run-times of these random quantum circuits on classical computers. For the circuits they used to claim quantum supremacy, they estimated their classical computational cost by running portions of the circuits on Google's Summit supercomputer and clusters, then scaling the resultant cost. One example of the difference between Google's classical cloud servers and their Sycamore processors is it took the quantum device 600 seconds to run the circuit three million times, and it was predicted that 50 trillion core hours and 10^{15} watt/hours to run on Google's Cloud servers. Essentially, Google used an algorithm that created a set of quantum circuits that a quantum computer could quickly run but took exponentially more time to run on the then-world's fastest supercomputer (Arute et al.). Google has demonstrated quantum advantage, but what does the future entail for quantum computing?

Future of Quantum Computing with Quantum Advantage

Quantum advantage can be increased in the future, and with more qubits being added to quantum processors, new and more advanced quantum algorithms can be run on quantum computers. We must consider the improvement of quantum processors now that they have reached demonstrable quantum advantage. Google claims that quantum processors will increase at a double-exponential rate, following a quantum equivalent of classical computing's Moore's Law (Arute et al.). To achieve this growth, quantum error correction methods will have to be developed to allow for the scalability of qubits on quantum processors. Additionally, Google is using its Sycamore quantum processor currently for quantum physics and quantum chemistry in the near term. Google wants to release processors that can achieve quantum advantage to

companies and researchers. Finally, Google's primary goal is to achieve a fault-tolerant quantum computer so it can be used for applications, including designing new materials (batteries and fertilizer catalyzers) and medicines (Martinis & Boixo).

Quantum advantage has been claimed numerous times with proof, but only for situations that did not have widespread commercial (practical) applications. In the future, quantum advantage can help complete practical tasks faster. More quantum error correction is needed to implement algorithms like Shor's Algorithm (integer factoring algorithm). By 2024, companies like IBM are planning to develop error-mitigation techniques that are successful enough to create quantum computers with thousands of qubits, allowing for more use cases to be unlocked ("*IBM Quantum Computing*"). Once quantum computers can start to scale up to thousands of qubits, there are many fields where quantum computers can demonstrate quantum advantage. Note that the "quantum market value" referred to in the next center refers to the total potential financial size of the market (ex. Predicted to be valued at 909 million USD in 2025). Finally, three fields that have the potential for large-scale quantum usage are finance (28% of overall 2019 quantum market value), energy and materials (16% of overall 2019 quantum market value), and medical products (9% of overall 2019 quantum market value) (AIMultiple). Quantum computing has a bright future, but when can we expect the development of ideal quantum hardware?

Revisiting The Idea of Number of Qubits - Predictions

With the rise of quantum computers, their limitations are becoming more noticeable. To remedy this, quantum hardware has improved in two ways: the number of qubits or a lower qubit error rate. Combined with error correction, these methods can lead to fault-tolerant quantum computers. We will analyze data related to the number of superconducting qubits because they were used in Google's 2019 demonstration of quantum advantage. Additionally, superconducting qubits are especially easy to manipulate, prepare, measure, and allow for easy tuning of the individual electrical circuits of each superconducting qubit (Kjaergaard et al.). Moreover, the electric circuitry of superconducting qubits allows for easy production of superconducting qubits with current chip manufacturing technologies. This quantum system is also one of the most researched and funded forms of quantum computing. We will focus on events from 2014 and onwards, which will be aggregated into a data set and used to find an equation of best fit. See the

appendix for a document with the data used for this section. For the data in Figure 6, note that there are other quantum processors, but the ones used have the most associated data.

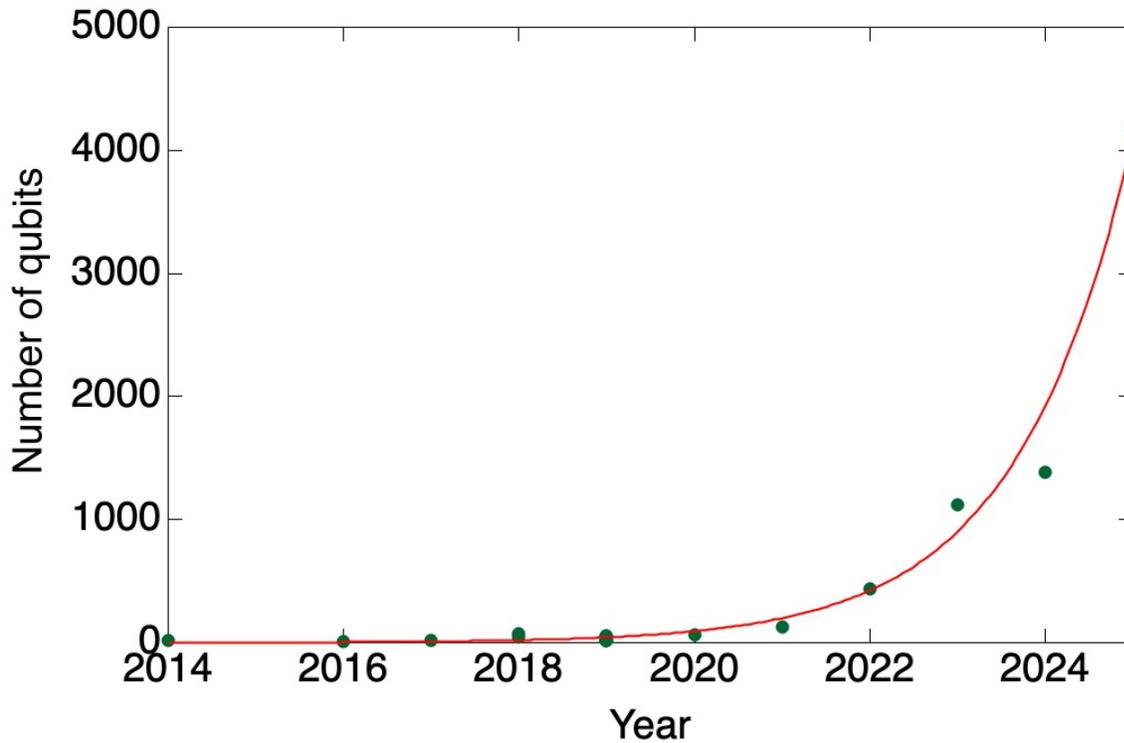


Figure 6: Graph of Data Points and Equation of Best Fit - Number of Qubits. *The chart gives all of the data points to form a shape that resembles an exponential function and shows the function $g(x) = 2.13^{(x-2014)}$, where x -value are years.*

The graph of Figure 6 indicates an exponential growth around 2.13^n , where n the number of years since 2014. Moore’s law, which has predicted the growth of classical processors by their number of transistors, predicts the number of transistors in a classical computer chip would double every 1.5 years, indicating a growth rate below 2^n (Corporation). Additionally, Moore’s law is predicted to become an overapproximation. Based on this prediction, the growth rate of classical computer processors is slowing down, but the growth rate of the number of qubits in quantum processors is increasing. Within the next few decades, a quantum computer can be large enough to implement advanced quantum algorithms. For example, considering Shor’s Algorithm, it is predicted that 2050 logical qubits (one logical/error-free qubit = 1000 current error-prone/physical qubits) will be needed to break the RSA protocol (the protocol uses a large integer that needs its prime factors to be found for the protocol to be decrypted) (LeWoody).

Using $g(x)$, by 2034, we should have enough error-prone qubits to run Shor's algorithm. This would only apply to superconducting qubits because error rates and correction codes vary for different quantum systems. In the end, according to our models, we will be able to develop enough qubits to implement algorithms that allow quantum computers to have a significant impact on our digital society. What about other factors that are currently affecting quantum hardware?

Revisiting Quantum Error Rates - Looking at Error Rates of Quantum Processors

We must also look at another limitation of quantum hardware, their error rates. In Google's experiments, the error rate for the largest quantum circuit used was 99.8% (Arute et al.). We will now gather data about the error rates of different quantum processors over multiple years, create graphs with modeling equations, and make predictions. An error rate is a measurement used to determine the reliability of a quantum circuit, and as an extension, a whole quantum processor ("*Fidelity Estimation for Quantum Computing Systems*"). A perfect quantum circuit would have a 0% error rate, but this is impossible. The minimum error rate for fault-tolerant/low-error quantum devices with hundreds of qubits for superconducting quantum devices is approximately 1%. Still, all devices with an under 1% error cannot be scaled to develop a fault-tolerant quantum processor ("*Error Rate*"). Also, the sources used for the data points use fidelity rates, which is a measurement used to determine the frequency of errors happening in a quantum circuit, and as an extension, a whole quantum processor ("*Fidelity Estimation for Quantum Computing Systems*"), making error rates = $1 - \text{fidelity rates}$. See the appendix for a document with the data used for this section. In regards to the data in figure 7, note that there are many other quantum processors, but the processors used have detailed data and are well-known.

Error Rates of Quantum Processors from 2016-2022

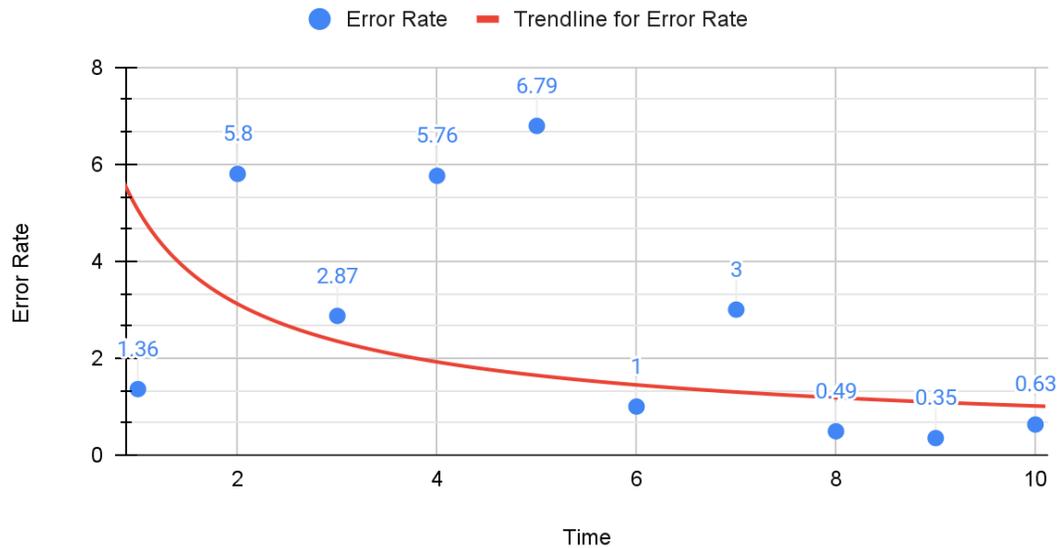


Figure 7: Scatter Plot of Data Points - Error Rates - With Equation of Best Fit. *The figure shows a scatter plot with a line of best fit. As many data points happen over the same year, each point will be equally spaced (by time, but not with yearly or constant intervals) in the graph. Also, a linear model is not suitable for this dataset.*

The equation of best fit for figure 8 is $f(x) = 5.06 * x^{-0.694}$. Using $f(x)$, within the next decade we should see quantum processors with a 1% error rate, but if we want to see a device with a 0.1% error rate, the fit predicts that 286 years are needed. While this growth rate is slower than classical computers and other aspects of quantum hardware, this factor, which allows for quantum computers to have more fault-tolerant qubits and not have to use a majority of their qubits for error corrections, can still improve enough in the near future. Should this prediction be the case, by the time many factors for quantum computers should be fully developed (20 years), the error rate would be 0.63%. By 2050, a quantum computer with usable error correction to sustain many qubits will be possible. What remains to be seen is the development and implementation of quantum algorithms, in addition to the ability for the quantum advocates to use the noise from more quantum advantage demonstrations to get funding to continue to develop quantum computers in the future. With the near-term possibility for a near-perfect quantum computer, quantum advantage demonstrations will become more common, and

quantum computers could be able to run algorithms like Shor's Algorithm and Grover's Search Algorithm.

Conclusion

In this paper, we covered essential concepts related to quantum advantage, including quantum bits, gates, and the unique properties of quantum bits. Then, we covered the limitations of quantum devices, quantum advantage, and computational complexity, all key to understanding Google's quantum advantage claim. We then analyzed Google's 2019 claim of quantum advantage, explaining the methods used to claim quantum advantage. From there, we analyzed the number of qubits in superconducting processors and the error rates of superconducting systems to make mathematical predictions for developing these two limitations of quantum systems. The data regarding the number of qubits supports the idea that quantum computing has the potential to grow faster than classical systems, leading to more uses of quantum computers within the next decade. Our analysis of error rates in different quantum systems led to the belief that near-fault-tolerant quantum processors will be possible by 2050.

We were able to demonstrate that quantum computers have the potential to be faster than classical computers (in some cases). However, it is important to note that classical algorithms and processors are still improving. Regarding Google's quantum advantage claim, China's Sunway TaihuLight classical supercomputer was able to run the simulation algorithm Google used in its classical tests. It took 304 seconds (Liu et al.), only 104 seconds slower than Sycamore and magnitudes faster than Google's original 10,000 years prediction and IBM's claim of 2.5 days. Moreover, physicist Pan Zhang, who helped create the algorithm used by the Sunway supercomputer and the algorithm IBM used for its 2.5-day claim (by using more RAM), made a faster classical algorithm. If given a larger classical supercomputer, this algorithm could complete the same operation in dozens of seconds (Pan et al.), faster than Google's Sycamore processor. Also, in August 2022, a group from the Chinese Academy of Sciences in China (led by Pan Zhang) was able to use 3D tensor arrays to model Google's Sycamore quantum processor to classically simulate the same calculations done in 2019 in 15 hours. They predicted only a "few seconds" would be needed if they were given a classical supercomputer (Coldewey). While quantum advantage has been shown and quantum computers are developing, classical devices and algorithms are currently growing fast enough to counter most claims of quantum advantage.

After learning about quantum advantage, viewing Google's quantum advantage claim, and predicting the development of two factors for improving quantum hardware, we can only wait to see if we can finally create a quantum computer that will have similar amounts of fault-tolerant qubits and low error rates as the classical bits found in the supercomputers of today. Ultimately, it is important to note that we are currently at the threshold of quantum advantage. We now have enough usable qubits to perform calculations that are too computationally complex for any current classical device to simulate in a reasonable amount of time.

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Smart treadmill for Alzheimer's patients By Zihan Zeng

Abstract

Alzheimer's disease is one of the common diseases in the elderly population, scientific and effective exercises, such as jogging, can stop the deterioration of Alzheimer's disease. The treadmill commonly used by the general population does not automatically adjust its own speed and does not perfectly match the gait frequency of the elderly, making it a factor that prevents the elderly from effectively exercising through jogging. Nowadays, with the existing and applied technologies, such as gait analysis, plantar pressure sensor and flexible sensor, the automation of treadmill can be significantly improved, and the physical activity energy expenditure (PAEE) of elderly people using treadmill can be made by the sensor to adjust the speed of the treadmill to suit the running frequency of the elderly to reduce the risk of falling when the elderly people exercise. These new technologies can be applied to treadmills to improve the exercise effect of Alzheimer's disease patients, and its treatment and intervention can play a significant supporting role. The application of fall-proof smart treadmills for exercise has significant medical and social implications. This paper compares the development of gait analysis, introduces the common experimental and simulation methods in gait analysis, combines flexible sensors to collect physiological data and the analysis of PAEE to assess the fall risk of Alzheimer's patients and promotes the development of smart treadmills.

Keywords: gait analysis; flexible sensor; physical activity energy expenditure; plantar pressure

Introduction

The senile dementia, also known as Alzheimer's disease, has no specific treatment so far, and the only feasible way is early detection and intervention. In order to prevent and improve Alzheimer's disease, proper physical activity is very beneficial to the health effects of the elderly, as lack of exercise and bed rest all day can aggravate the damage to the brain. Some studies have shown [1] that exercise can activate nerve cells to delay the decline and has a better maintenance effect on the cognitive function of the brain, which has a role in alleviating dementia. Patients with Alzheimer's disease can help improve their mood if they exercise regularly in their daily life, and they can also keep their muscles and heart healthy, and long-term exercise can also

promote sleep and prevent constipation. But older people exercise to be more conservative, such as jogging or brisk walking, aerobic exercise for half an hour a day. How to complete this slow walking and aerobic exercise? The treadmill is a good choice because it is not limited by climate and environment [2]. However, the ordinary treadmill has some problems for the elderly whose mobility is not very convenient and inconvenient when using it, the first one is to prevent falls. The second is how to determine the appropriate intensity of exercise. If an intelligent treadmill suitable for Alzheimer's elderly is researched, it will be a more effective role of lifestyle management with exercise as one of the core elements in the prevention and treatment of chronic diseases.

Due to the complexity and uncertainty of human movement, it makes the research of fall behavior recognition involve the intersection problem of motion biomechanical information acquisition, artificial intelligence, flexible sensor and other disciplines. How to obtain kinematic, kinetic and physiological information of human fall behavior from multi-sensors, establish a mathematical model of human fall process in accordance with the principle of motion biomechanics, so as to effectively detect and predict the human fall behavior process and reduce the injury caused by the elderly fall has become a new research hot spot and difficult problem in the intersection of sensing information acquisition, pattern recognition, health management and medical fields. It has high research value and application significance.

Gait is the behavioral characteristic of human walking, with periodicity and directionality. Normal gait is the gait of the human body in its natural state, which is an important condition to ensure the stability of the body. However, due to the decline in the coordination and control of neurological, muscular, skeletal and other bodily functions and response to unexpected events, the gait of the elderly changes in response to various walking situations, causing the risk of falls. The gait analysis is an objective measurement method currently used to predict fall risk, guide fall prevention and evaluate intervention effects.

With the development of modern measurement techniques, gait analysis has gradually changed from a qualitative study to a quantitative study of kinematics and kinetics of human walking in various parts of the body, and gait analysis has gradually developed into an important branch of biomechanics. Gait analysis is not only a necessary tool to investigate the intrinsic causes of gait variability, but also an important method to reveal the mechanism of maintaining stability during walking.

The study of human gait has a long history. From 400 to 300 B.C., Aristotle in ancient Greece began to notice walking movements. In the early 16th century, Europeans began to study the movements of animals in running in order to predict the chances of winning horse and dog races, using continuous image taking to record the periodic limb positions of animals and analyze them [3]. In the 17th century, people began to combine mechanics and anatomy to study the coordination patterns of human and animal movements. The invention of the camera and the video camera in the 19th century brought a new era of progress in the study of human gait analysis. The American Mae Briggs used 24 cameras to take continuous photographs of horse running movements and used the photographs to calculate the necessary parameters, which was the beginning of objective kinematic gait analysis and laid the foundation for the methods of image measurement and analysis. With the development of modern technology, by the 1960s, the advent of computers can be considered a watershed in gait analysis research, which opened the digital era of gait analysis research. With the powerful computing power of computers, researchers could systematically quantify and analyze the experimentally collected gait data. On this basis, especially the development of a three-dimensional spatial motion analysis system transformed the simple description of walking into a quantitative analysis from a biomechanical perspective. Significant technological inventions and historical events in the development of gait analysis are of great significance. In addition, the emergence of high precision equipment such as surface electromyography measurement systems and plantar pressure measurement systems has provided greater possibilities for the experimental design of related research. With the help of new experimental equipment, such as electromyography analysis and plantar pressure distribution analysis have been gradually applied to gait analysis, making gait analysis more comprehensive and greatly expanding the application areas of gait analysis [4].

Directions

I. Gait analysis: Gait analysis main content

During human walking, a complete gait cycle, called the gait cycle, is formed from the time one heel hits the ground until that heel hits the ground again. A gait cycle consists of a series of typical postural changes, each of which corresponds to a period of time called the gait phase: Stance Phase and Swing Phase. The phase of gait in which the foot is always in contact with the ground is the Stance Phase, otherwise it is the Swing Phase, see Fig. 1.

The parameters describing gait include spatio-temporal parameters, kinematic parameters and kinetic parameters. Among the spatio-temporal parameters of gait, besides gait period and gait phase, they also include: gait speed, gait frequency, gait length, gait width, gait direction angle, etc. A healthy person usually walks at a speed of about 65-95 m/min and a stride frequency of about 95-125 steps/min. Step length refers to the longitudinal distance between the left and right heel (or toe) when walking, also known as single step length, see Fig. 2 in A; step width is also known as stride length or compound step length, is the distance between the same side of the heel 2 times on the ground, so it is usually 2 times the step length. See Fig. 2 in B; step width is the horizontal distance between the center of the two heels or gravity point, see Fig. 2 in C; walking in the direction of forward and the long axis of the foot formed by the angle known as the step angle, healthy people about 6.75° , see Fig. 2 in D.

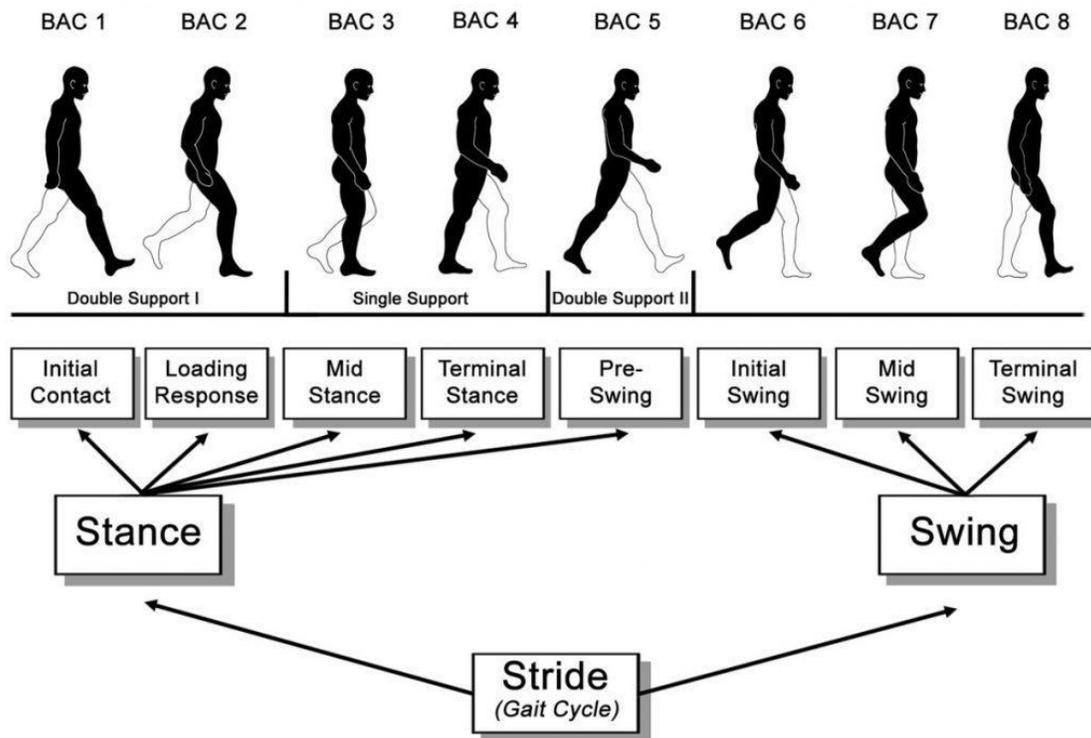


Fig.1 Gait phase division

Fig. from: Stöckel, Tino & Jacksteit, Robert & Behrens, Martin & Skripitz, Ralf & Bader, Rainer & Mau-Moeller, Anett. (2015). The mental representation of the human gait in young and older adults. *frontiers in psychology*. 6. 943. 10.3389/fpsyg.2015.00943.

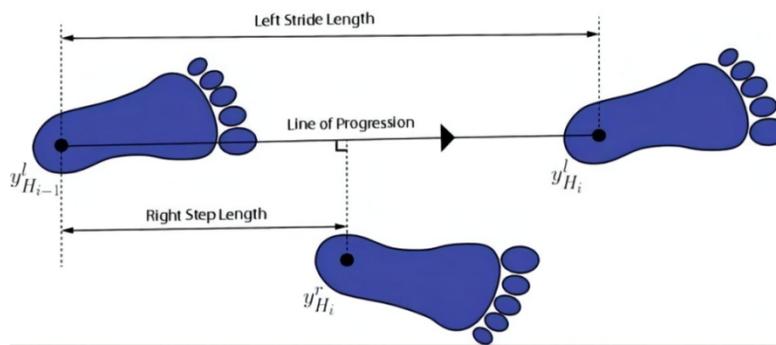


Fig.2 Gait spatial parameters

Fig. from: Motian, S., Pergami, P., Guffey, K. et al. Automated extraction and validation of children's gait parameters with the Kinect . BioMed EngOnLine 14, 112 (2015).

Experimental methods for gait analysis/Development of experimental methods

In the initial stage of gait analysis, experiments were mostly based on observational methods and primary image resolution [5, 6]. The method is low-cost and easy to apply, but there are certain disadvantages, such as extremely low efficiency when the group of subjects is large, which limits the comprehensiveness of the study; it is influenced by subjective factors such as equipment and experimental personnel, which is not conducive to the accuracy and reliability of experimental results. From the initial recording of human changes by drawing and other means to the modern image analysis method later applied with the help of high-speed cameras and three-dimensional motion capture systems, gait analysis has gradually advanced to quantitative analysis. Fliker et al [7] established a visual gait laboratory and proposed a user-friendly gait analysis method. Other researchers have used wireless accelerometers to assess the gait characteristics of patients with osteoarthritis of the knee (KOA), enabling a qualitative and quantitative assessment of gait in KOA patients with strong clinical implications. In addition, there are numerous studies that have attempted to apply Kinect sensors [8] with devices such as treadmills [9] for gait analysis.

Commonly used experimental equipment

Commonly used equipment for gait experiments can be divided into three main categories: motion capture systems, surface electromyography systems, and plantar pressure

measurement systems.

1). Optical motion capture system. With the help of infrared high-speed cameras to capture the human body in three-dimensional space, the trajectory changes, and through the form of spatial coordinates output data. In the optical motion capture industry, the Vicon series of products designed and developed by the British OML (Oxford Metrics Limited) are widely used in gait analysis with the advantages of early start, high accuracy, and strong expandability, see Fig.4. In this field, in addition to Vicon, Motion Analysis, Optitrack, Nokov and other brands are also widely used. These products play an important role in motion analysis [10-11], exoskeleton robots [12-13], UAV product development [14], and film and game industries [15]. The force measurement table is used with an optical motion capture system to output kinetic parameters such as ground support forces, forces and moments of each joint during human motion simultaneously [16-18].



Fig.4 Vicon motion capture system

2) surface electromyography measurement system. The changes of EMG signals in human motion are captured in real time, and after amplification, filtering and analog/digital conversion, the quantified EMG waveforms and data are formed. Because of its safety and non-invasive measurement advantages, it has attracted much attention in the rehabilitation medical engineering community and biomechanics research. The telemyo surface electromyography measurement system developed by Noraxon is typical, which can be synchronized with the Vicon motion capture system for a more detailed characterization of the gait [19], see Fig. 5.



Fig.5 Telemyo surface electromyography measurement system



1-Pressure insole; 2-Connecting wire; 3-Bluetooth receiving device; 4-Data transmission optical fiber; 5-USB adapter; 6-Elastic strap; 7-Battery and connecting wire; 8-Battery charger; 9-Triggering device ;10-Bluetooth password

Fig.6 Novel Pedar-X plantar pressure measurement system

In gait experiments, the motion capture system, surface electromyography and plantar pressure measurement system are often combined to collect data simultaneously. The Nexus software that accompanies the Vicon motion capture system is highly extensible, and the data can be quickly integrated into the force table, surface electromyography, and plantar pressure measurement equipment through the reserved data interface to record data simultaneously.

Simulation method of gait analysis

Inverse dynamics is the use of the laws of mechanics based on the appearance of the motion of an object to solve for the expression of the forces that make the object change [20]. In biomechanical research, with the help of gait experimental data, researchers can find parameters such as muscle moments by inverse dynamics methods according to the research needs [21]. Several software for gait analysis simulation have been developed based on the principle of inverse dynamics. At present, the more mature ones are AnyBody, Opensim, LifeMOD, etc.

II. Flexible sensor

In addition to motion capture, electromyography and foot pressure and other conventional data acquisition, but also need to monitor and collect other human physiological signals in real time, applicable to the movement of the sensor needs to have high sensitivity and stretch. Since traditional metal and semiconductor sensors are not suitable for this purpose, flexible sensors with the above-mentioned advantages are attracting attention in the field of human physiological signal monitoring. Among them, graphene is the thinnest and strongest two-dimensional carbon material known, with excellent electrical conductivity and flexibility, and is the preferred sensing material. Graphene/polymer flexible sensor can not only monitor large human physiological signals, such as human joint movements (including finger joints, elbow joints and knee joints bending movement), but also can be used for monitoring small signals, such as health monitoring (including pulse, heart rate, breathing, etc.), which can be integrated into clothing to make the clothing with corresponding functions and achieve intelligence.

The sensing mechanism of graphene/polymer flexible sensor mainly includes piezoresistive mechanism and capacitive mechanism, among which, the piezoresistive mechanism is the most common. The sensing mechanism of piezoresistive flexible sensor is to convert the change of external force into the change of resistance of the flexible sensor; while the

sensing mechanism of capacitive type is to change the charge holding capacity of the flexible sensor by the change of external force, causing the change of capacitance. It can be seen that the above-mentioned different types of flexible sensors are all mechanisms of converting force signals into electrical signals, so the core properties of flexible sensors are mechanical and electrical properties.

The mechanical and electrical properties of the graphene/polymer flexible sensor depend mainly on the mechanical and electrical properties of the graphene/polymer flexible conductive material itself. Graphene/polymer materials combine the excellent properties of graphene materials and polymer materials, and the performance of graphene/polymer flexible sensor is introduced from both mechanical and electrical perspectives. The smart garment senses the physiological signals (joint movement, breathing, heart rate, etc.) of the human body through the graphene/polymer flexible sensor. The changes of human physiological signals will cause the flexible sensor to generate electrical signals that can be recognized and processed, and then the data acquisition and processing module will convert the measured signals into digital signals and store the signals or transmit them to the central node (computer, cell phone, etc.) through wireless transmission devices to finally achieve real-time monitoring of human physiological signals and feedback from doctors or professionals based on the monitoring results. The embedding of a graphene/polymer flexible sensor can realize the functionality of smart clothing. The performance of flexible sensors is the key to realize the function of smart clothing. Indicators characterizing sensor performance include sensitivity, linearity, repeatability, hysteresis, response time, detection range, etc. In order to meet the specific functional requirements of smart garments, flexible sensors with corresponding performance need to be embedded, and different sizes, shapes, and configurations of flexible sensors need to be designed according to the actual functional requirements of smart garments.

In terms of human joint motion monitoring, relevant research mainly monitors the flexural motion of human joints through graphene/polymer flexible sensors, which are usually characterized by joint flexural angle values. Compared with pulse rate and heart rate, the flexible sensor is required to have good stretchability and a relatively wide detection range. In addition to pulse, heart rate, and respiration monitoring, the graphene/polymer flexible sensor can also monitor small skin deformations caused by pulse, heart rate, and respiration, which require high sensitivity and low detection limits. Song et al [22] applied the prepared graphene/carbon

black/silicone rubber flexible sensor to the human wrist for pulse signal monitoring, and as a result, significant pulse waveforms were observed, i.e., the sensor can achieve accurate monitoring of pulse signals. In the fields of medical rehabilitation and sports and fitness, the graphene/polymer flexible sensor is integrated into sports undershirts, sports wrist guards and other clothing carriers to monitor human respiration, heart rate, pulse, etc., which can effectively determine the state of the human body and help develop appropriate medical and exercise programs. Current research often focuses on the preparation and basic performance testing of the flexible sensor, and most of the prepared flexible sensors are directly attached to the surface of clothing or human skin for functional verification of human physiological signal monitoring, which can be used for initial testing of sensor performance and functional verification, but not easy to promote the application, and the sensor position is uncertain, and the wearing experience is not good. Therefore, it is an important research direction to design the integration method of flexible sensor and clothing, and to explore the functional realization of smart clothing under this integration method.

III. physical activity energy expenditure (PAEE) analysis

The process of human movement is accompanied by the consumption of energy .In general, the greater the intensity of movement, the more energy the human body consumes. Since the energy consumption level can directly reflect the exercise intensity of the human body, it is important to obtain the PAEE level of the human body during exercise in time to understand the exercise load of the elderly and avoid the exercise risk. As the human exercise mechanism is more complex, PAEE is related to a variety of physiological factors such as muscle shaking, heart contraction and respiratory rate. Therefore, it is difficult to directly measure the PAEE level during daily exercise.

With the flexible sensor, the model is able to predict PAEE levels with over 85% accuracy. The recorded human physiological signs include acceleration, respiration rate, heart rate, chest skin temperature, electrical skin response, body temperature, and arm temperature.

The speed adjustment of the traditional motorized treadmill is still done through human-computer interaction such as buttons, and the freedom of the exerciser is greatly restricted [23].Therefore, it is important to study the motion characteristics of human body on treadmill and the law of speed change, and adjust the motor speed according to this law to

achieve the purpose of speed adaption of treadmill, which is important for improving the running experience of elderly people and expanding the application scope of treadmill.

The speed adaption of the treadmill has become a popular research topic in recent years. At present, domestic and foreign research on speed adaptive treadmill has various attempts, and has made some progress. For example, through the device tied to the human body, the real-time detection of the human body's state, as well as through gestures and other discriminative acceleration and deceleration intentions [24]. There are some bottlenecks in such methods: Acceleration and deceleration are prone to misjudgment; the human body is difficult to control and prone to acceleration and deceleration oscillations; the detection device tied to the limb affects the normal movement of the human; the operation is not simple enough and prone to misuse, etc. [25].

IV. Discussion

1. Lack of fall and energy consumption function becomes an auxiliary barrier
2. Automatic adjustment such as step speed can assist
3. Measurement solves the problem of energy consumption

Nowadays, in the general environment of a pandemic, running in public areas has become a difficult task due to government control and the public's consideration for their own safety. However, daily exercise is still indispensable for the public, so running indoors with the help of running equipment has become a popular choice for the public. Many people will use treadmills to exercise indoors during home quarantine, so that they can get effective exercise even in the general environment of the pandemic. However, for some elderly people with Alzheimer's disease, there are some inconveniences in using traditional treadmills, such as the inability to predict and prevent the risk of falling, or the inability to adjust the exercise intensity, which makes it inconvenient for people with Alzheimer's disease at the operational level. In this paper, we describe how the treadmill can be operated more conveniently and improve the exercise effect of Alzheimer's patients with the help of existing technology such as flexible sensors, plantar pressure and energy consumption analysis[22].

Firstly, the human body image in the video split-frame image is obtained by image processing; the feature points are extracted from the obtained image; the feature data is analyzed and the mathematical model between it and the treadmill motor speed control is established by

gait analysis. The adaptive control method of treadmill speed based on image processing does not need to install any device on the sportsman, but only needs to capture the posture characteristics of the sportsman through the camera to control the motor speed and follow the changing trend of the sportsman's speed, which can realize the following control of treadmill speed within a certain range. Meanwhile, the flexible sensor can detect the physiological signs of the human body during exercise, including acceleration, respiration rate, heart rate, chest skin temperature, skin electrical response, body temperature, arm temperature, etc.

Secondly, the application of sensing technology in the development of an intelligent treadmill control system can meet people's requirements for fitness quality and play a positive application benefit. The application of sensing technology and optimization of intelligent treadmill control system can not only give the gym-goers can bring a new intelligent experience of running and fitness, compared with the traditional motorized treadmill, the freedom of the exerciser will be greatly restricted due to the process of intervening in the manual adjustment of equipment data [23]. Thus, it is important to study the motion characteristics of human body on the treadmill and the speed adaptive function, which can help to improve the running experience of the elderly and broaden the use of treadmill, etc. with great prospect. Meanwhile, the intelligent treadmill control system is optimized and designed through sensing technology to avoid the monotony of indoor exercise and enhance the fun of indoor running and fitness.

Again, the physiological indexes are detected and data are collected to calculate energy consumption, which lays the foundation for further research. With the depth of research and the progress and development of industrial technology in related fields such as Internet, Internet of Things and sensors, the research of speed adaptive treadmill may integrate multi-dimensional parameters such as mechanics, visual image, 3D, heart rate and neural intuition, and combine technologies such as cloud computing and big data to continuously expand from simple speed adaptation to higher dimensional intelligence, which is also the focus of future research. Future research on gait analysis should focus on identifying relatively standardized, efficient, and universal operational procedures and protocols, standardized testing platforms, including the data collection systems used and the corresponding data analysis methods, so that gait analysis can be performed more quickly and effectively in different settings (e.g., clinical research centers, communities, homes, etc.) and facilitate comparisons among relevant studies. and facilitate comparisons between relevant studies. Longitudinal analysis of larger cohort populations is also

needed to explore critical thresholds for dual-task related gait changes and to analyze relevant confounding factors for effective motor interventions in Alzheimer's disease populations. By innovating and developing more gait kinematic analysis methods, multi-task paradigms, standardized detection platforms, standardized sensor placement and parameters, and expanding more clinically meaningful gait parameters, such as heel-palm shift, heel-in angle, and toe-out angle, researchers can establish early screening and differential diagnosis oriented by gait analysis results, and thus truly apply them to This will allow the researchers to establish early screening and differential diagnosis based on gait analysis results, which can be applied to large-scale clinical work.

Exercise is an effective way to improve balance, mobility, and lower extremity strength in older adults, and improvements in these physical functions are strongly associated with improved performance in performing functional activities and a decreased probability of falling. However, the training must be of sufficient intensity and periodicity, and the exercise intervention must be designed and refined to address the root cause of the imbalance. As the main object of gait analysis, the way people move and how they feel is always the focus of the researchers.

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The Dawes Act of 1887 and Its Detrimental Effects Towards Native American Agriculture

By Kexiang Huang



Native American history did not conclude with the Trail of Tears, nor were indigenous people always relegated to living on reservations and their curtailed tribal territories. There was a chapter in American history where Native Americans were encouraged to assimilate into American society through the adoption of capitalist values and the practice of subsistence farming. The Dawes Act of 1887, signed by President Grover Cleveland, served as the cornerstone of this chapter.¹ The Act authorized the US government to divide Native American reservations into individual allotments of private property for Native heads of families and households and included a host of provisions for administering the land.² Ownership for all Native allotted land would remain in trust for twenty-five years, and to encourage farming, allottees were supplemented with vocational education by government agents and religious instruction that taught the importance of individualism over tribalism.³ Carlson noted that “Reformers in the 1880s were convinced that allotting land to Native Americans would encourage each family to farm its own land and, in so doing, acquire the habits of thrift, industry and individualism needed for assimilation into white culture.”⁴ As a result, the Dawes Act was

¹ “Dawes Act (1887).” (Feb 8 2022) National Archives and Records Administration. National Archives and Records Administration. Accessed May 6, 2022.

² Ibid.

³ Berthrong, Donald J. “Legacies of the Dawes Act: Bureaucrats and Land Thieves at the Cheyenne-Arapaho Agencies of Oklahoma.” *Arizona and the West* 21, no. 4 (1979): 336.

⁴ Carlson, Leonard A. “The Dawes Act and the Decline of Indian Farming.” *The Journal of Economic History* 38, no. 1 (1978): 276

meant to be a means of assimilating Native American tribes into white society by constituting a transformation of this group's socioeconomic makeup—thereby encouraging self-subsistence farming through a shift from tribalistic self-government and collective ownership to adopting citizenship and the private ownership of land. Although the Dawes Act intended to encourage subsistence farming in Native American Reservations between the years 1887 and 1934 by offering the privatization of land, the act ultimately hampered their agricultural output by ceding “surplus” lands to non-natives and homesteaders, creating unproductive divisions of land ownership, incentivizing Natives to lease their land over farming, and making Native lands susceptible to fee patents.

Research by Wessel indicates that prior to allotment, Native Americans had already possessed a thriving agricultural economy. The Five Civilized tribes (Cherokee, Chickasaw, Choctaw, Creek, and Seminole) produced over “69 percent of the wheat grown on Indian reservations, 81 percent of the corn, and over 43 percent of the vegetables.” This data suggests that within the communal tribal structure of Native society, Natives already had the ability to “Sustain a prosperous agriculture economy.”⁵ Research by Carlson also demonstrated that according to the acres cultivated per capita, “18 of the 33 reservations had compounded rates of [agricultural] growth in excess of 10% per year, including four which had growth rates in excess of 20% per year.”⁶ The Dawes Act only served to diminish that agricultural potential.

The Dawes Act treated Native American land remaining after allotment as “surplus lands” to be ceded to the Federal government, which were later occupied by Non-whites and homesteaders, leading to the alienation of significant Native-American populace critical for agricultural activity.⁷ When the act was implemented in reservations across the US, most of the land that was left over after allotment and in most cases valuable to agriculture was declared as “surplus” lands that were either sold or transferred by the federal government to non-Indian parties.⁸ Case studies from the Winnebago reservations revealed that “Not coincidentally, through the provision for surplus land sales . . . allotment permitted the penetration of the remaining Indian lands by white ranchers and farmers.”⁹ Furthermore, in a minority report of the

⁵ Wessel, Thomas R. “Agriculture, Indians, and American History.” *Agricultural History* 50, no. 1 (1976): 11

⁶ Carlson, p. 3

⁷ Native Lands Information System. “The General Allotment Act of 1887 Crippled Native Agriculture for Generations.” Native Land Information System, 2012.

⁸ Ibid

⁹ Krezenski, Matthew J., “Repercussions of the Dawes Act: Leasing, citizenship and jurisdiction on the Omaha and Winnebago Reservations, 1887-1896” (2001): 504

House Committee in 1880, which examined the Catawba Tribe, an official had pointed out that much of the Native land had "gradually withered away under the policy, until there was not one of [the tribe] to attest to the fact that they ever existed, and their lands fell prey to the whites who surrounded them, and steadily encroached upon them"¹⁰ This demonstrates how entire tribes of territory could dissociate after allotment. Carlson commented that after allotment, most Indian farmers had smaller farms, smaller incomes and became more vulnerable to economic fluctuations than white farmers.¹¹ Thus, the ceding of "surplus" lands revealed an exploitative result of the Dawes Act, within it containing the consequence of expropriating land away from Native Americans, ultimately shifting land and agricultural power to Non-native landholders.

The allotment policy restricted Natives to only small portions of land as the rest were alienated and given to non-whites. In the Cheyenne-Arapaho tribes of Oklahoma, a total of 18 acres, or 34.3 percent, of all their allotted land was alienated.¹² By adding land sold during the Roosevelt and Taft administrations, about 297,214 acres, or 56.3 percent of all land allotted to the tribes, had passed from their possession.¹³ Wessel states that "In most instances, its consequence was to reduce those farming areas that had prospered to small acreages incapable of supporting a family."¹⁴ We see this claim reflected in when in 1906, D. W. C. Duncan, a Cherokee, spoke for his people when he reported to a Senate committee that before allotment he had farmed 300 acres, which came from the communal land rights that he held as a tribe member.¹⁵ After the division of his reservation, however, he was reduced to making a living on only 60 acres of property, showing that before allotment, most Native Americans farmed beyond the property that was designated by the Dawes Act.¹⁶ The act also incentivized the Federal government to sell Native lands that were considered "incompetent," for function, adding to the total number of surplus lands sold. According to research by Otis in 1973, of the 155,632,312 acres of Indian lands in 1881, only 77,865,373 acres of lands resided as Native American property, thus the total land held by Indians was cut nearly in half as a result.¹⁷ Wilson estimates that approximately 38,000,000 acres of land were alienated through the ceding of surplus land.¹⁸

¹⁰ H.R. No. 1576, 46th Cong., 2 Sess., 8 (1938).

¹¹ Carlson, p. 4.

¹² Bethrong, p. 16.

¹³ Ibid p. 14.

¹⁴ Wessel, p.11.

¹⁵ Wayne Moquin and Charles Van Doren, eds., *Great Documents in American Indian History* (New York: Praeger, 1973): 286

¹⁶ Ibid

¹⁷ Landsman, Gail. "The Ghost Dance and the Policy of Land Allotment." *American Sociological Review* 44, no. 1 (1979): 3

¹⁸ Perdue, Theda. "The Legacy of Indian Removal." *The Journal of Southern History* 78, no. 1 (2012): 3-36

Naturally, this reduction in ownership had major impacts on their agricultural capacity then and for the duration of the Dawes Act.¹⁹

The alienation of “Surplus Lands” from Native reservations becomes specifically harmful towards Native American agriculture in the case of a fractionated pattern of land ownership, increasing the difficulty of agricultural management. Lands held in trust, lands ceded to non-Natives, and lands still owned by tribes were mixed together on what was once a single reservation, creating a checkerboard pattern [see figure 1].²⁰ In most cases, alienated lands reduced the size of farming areas that had once prospered to small acreages of land incapable of supporting a family.²¹ The Indian Land Tenure Foundation modeled the process of checkerboarding which demonstrated how breaking unified reservations into small, fractionated patterns increased the difficulty of processes such as irrigation and ranching which required large consecutive sections of land.²² Checkerboarding prevented indigenous people from using “Lands that the tribe owns and uses in traditional ways” , creating jurisdictional challenges that ultimately hampered their agricultural output.²³ Paul noted that “checkerboarded” land had generational impacts, as “Allotments which remained in trust status became fragmented as the original allottees died and interest in allotments was divided among an increasing number of heirs.”²⁴ As each generation perished and as the number of owners of the land grew exponentially, it resulted in the highly fractionated ownership of Native American Land [see figure 2].²⁵ With the ceding of surplus lands alienating significant parts of the populace and demolishing the traditional structure of Native reservations, Native Americans were ultimately unable to make use of a new system of fractionated lands. Thus, the Act created an additional challenge to effective agricultural activity.

The increased difficulty of agricultural management caused by the ceding of surplus lands to non-natives also incentivized Native Americans to choose to issue agricultural leases over farming their own land. As the Dawes Act created official property rights recognized by the federal government where none had existed before, the Act offered Native Americans the

¹⁹ Native Lands Information System. “The General Allotment Act of 1887 Crippled Native Agriculture for Generations.” Native Land Information System, 2012.

²⁰ A Simplified Six-Generation Example of Undivided Ownership . 2012. Indian Land Tenure Foundation.

²¹ Wessel, p. 11

²² “Annual Report on the Issue of Checkerboarding.” Indian Land Tenure Foundation.

²³ Ibid

²⁴ Stuart, Paul. “United States Indian Policy: From the Dawes Act to the American Indian Policy Review Commission.” *Social Service Review* 51, no. 3 (1977): 455

²⁵ “Annual Report on the Issue of Checkerboarding.” Indian Land Tenure Foundation.

opportunity to lease and sell their lands whenever self-subsistence farming became unsuccessful—an practice that arose frequently during the years of Native allotment.²⁶ An agricultural lease was an agreement between a Native landowner and a lessee that stipulated the terms of use for that piece of farmland.²⁷ A research model created by Carlson in 1981 concluded that “allotment would discourage Indian farming,” and that an Indian family would devote fewer resources to its own farming, “choosing instead to lease some lands to whites and work for a wage.”²⁸ Thus the act ultimately contravened the stated intentions of the reformers to encourage Native Americans to become independent farmers. Due to the inexperience of indigenous people in farming small acres of land, securing credit, paying state and local taxes, and holding allotments often too small to be economically viable, Natives were incentivized to lease their land to non-whites as an alternative option to farming.²⁹ In 1892 an agent wrote: “Should the authority be given for Indians to lease their lands, nearly all would avail themselves of the privilege and their land would be immediately taken up by whites at ridiculously low compensation and the Indian would squander the proceeds and still live an idle, vagabond life.”³⁰ Local agents had no faith that the allotment policy would benefit indigenous people in agriculture and instead believed their land would be exploited by white people “at ridiculously low compensation,” as Natives were often inexperienced with negotiating land leases and setting reasonable rates. For the Omaha Winnebago tribes of Nebraska, for instance, Commissioner of Indian Affairs Thomas J. Morgan noted that within weeks, the Winnebagos had “not only been leasing their allotted lands to white people, but more alarmingly, they had also surrendered “entire control” of the land to them as well”.³¹ The repercussions of the Dawes Act and its creation of private land rights evidenced how Native Americans voluntarily gave up much of their economic potential tied to land ownership and independent agricultural activity, and instead, chose not to farm their own land.

Research from the Cheyenne Arapaho Tribes demonstrated how leasing lands was often connected with a complete idleness in agricultural activity, with Native American land mostly left unused. In 1900, Commissioner Will Jones commented that the widespread practice of

²⁶ Carlson, p. 2.

²⁷ “Dawes Act (1887).” (Feb 8 2022) National Archives and Records Administration. National Archives and Records Administration. Accessed May 6, 2022.

²⁸ Carlson, p. 4.

²⁹ Stuart Paul, p. 457

³⁰ Fuller, Lauren L. “Alaska Native Claims Settlement Act: Analysis of the Protective Clauses of the Act through a Comparison with the Dawes Act of 1887.” *American Indian Law Review* 4, no. 2 (1976): 271

³¹ Berthrong, Donald J, p. 336.

leasing in allotments often undermined the goals of the Dawes Act, stating that it “fostered indolence” as Native Americans were “allowed to turn over his land . . . and go on his aimless way.”³² By 1900, over 1,100 leases were signed by Cheyenne and Arapaho tribes, where these agreements covered over one-third of their land.³³ Eight years after allotment, only 15 to 18 percent of the adult male population actually occupied and cultivated the land, while the rest simply leased the land and worked for a wage.³⁴ At the Cantonment Agency, only 2,587 acres were cultivated independently by Native Americans out of a total of 92,859 acres of land, while 80,320 acres were leased to non-Indians (over 86 percent of the land was not used for subsistence farming).³⁵ The editor of a newspaper in Watonga, the seat of Blaine Oklahoma Territory, alleged that 69 percent of the original Cheyenne and Arapaho land was idle and unproductive.³⁶ Ultimately, the Natives' lack of understanding of capitalistic values and agricultural norms, as well as the increased difficulties of cultivating small acres of land prompted most Natives to forsake farming practice. Thus, as the Dawes Act permitted the issuing of leases, most Natives were incentivized to do so and transfer over the vast economic potential of their land to non-Natives.

The Dawes Act also made possible the issuing of agricultural “fee patents” to Native allotted land, thus making the land subject to taxation and exacerbating the loss of Native American land ownership. Wessel noted that “Government programs for encouraging agriculture floundered, with government farmers acting more as clerks and leasing agents rather than farmers or instructors.”³⁷ Fee parenting also opened Native lands to taxation, as “County officials were at the reservation agents' doors ready to add newly patented land county tax rolls. Unaccustomed to tax systems and often only vaguely aware of what land they owned, many Indians proved easy victims to purchase schemes and lost through tax delinquencies.”³⁸ The federal agency often exploited Native Americans through purchase schemes and tax delinquencies since Natives were often new and unfamiliar with concepts of land ownership and tax responsibilities in capitalism. The allotment policy had incentivized the federal government

³² Annual Report of the Commissioner of Indian Affairs [CIA], (Washington, 1900), 326

³³ Bethrong Donald J, p. 338

³⁴ Ibid

³⁵ “Records of the Bureau of Indian Affairs [BIA].” National Archives and Records Administration. National Archives and Records Administration, 1900

³⁶ Ibid

³⁷ Wessel, p. 19.

³⁸ Ibid

in 1900 to pass a series of legislations that passed the issue of free patent titles to individual Native Americans to the latter's detriment.

“Fee patenting” accounted for the sale of over 1,280,526 acres of allotted land between 1908 and 1934, which caused a surge of further non-native expansion.³⁹ The failure of the Act was also evidenced by an 1878 report of the Commissioner of Indian Affairs, demonstrating that five-sixths of the 1,735 Chippewas in Michigan who had received patents had lost their lands.⁴⁰ Axel Johnson, a superintendent on the Omaha reservations observed that only “13% of those who received free patents used their land productively; the other 7.1 percent of those sold their lands, the rest 80% had little or nothing to show for their lands.”⁴¹ Ultimately, fee patenting discouraged Native Americans from using their own land for agriculture.

Despite the apparent benefits of the Dawes Act in introducing private property and capitalist values to Native American society, the Act ultimately failed to integrate and enrich Native Americans in practice. Its intention to encourage subsistence farming in Native American societies only resulted in further reduction in their agricultural output and a loss of immense economic potential for the Native populace. Cotroneo stated that the Dawes Act directly “caused irrevocable loss of approximately 84 percent of the tribal holdings, a total economic and political destruction of the tribal entity, and an almost complete loss of individual initiative,” referring to the shift in Native American incentive structure.⁴² Not only did the Act fail in practice, but most Native Americans faced a continuing ignorance of the American system and practices as well as incongruence to assimilating culturally and achieving economic integration as the Act intended. Published in 1927, the Meriam Report became the most comprehensive survey of the Indian programs of the Federal government, which blamed the unanticipated consequences of the allotment policy on the government's insistence on allotting land to tribes that were unprepared for the individual ownership of property.⁴³ Ironically, the Dawes Act became another chapter in Native American history among numerous others that led to further west-ward expansion, the

³⁹ Perdue, Sonny. “United States Department of Agriculture.” List of Reports and Publications | 2017 Census of Agriculture | USDA/NASS, 2017.

⁴⁰ United States. Office of Indian Affairs Annual report of the Commissioner of Indian Affairs, for the year 1900, Part I Washington, D.C.: G.P.O., [1878]

⁴¹ Ibid

⁴² Cotroneo, Ross R., and Jack Dozier. “A Time of Disintegration: The Coeur d’Alene and the Dawes Act.” *The Western Historical Quarterly* 5, no. 4 (1974): 405–19.

⁴³ Meriam's, Lewis. “Meriam Report: The Problem of Indian Administration (1928).” Meriam Report: The problem of Indian administration; National Indian Law Library, Native American Rights Fund (NARF), 1928

exploitation of Native populace and the forceful shifting of economic and political power away from the Native Americans' tribal homeland.

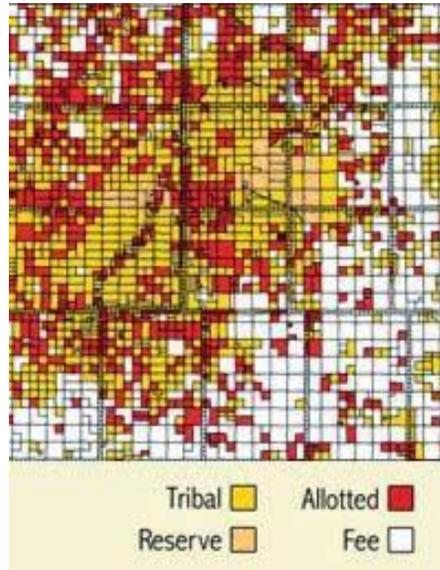


Figure 1 Checkerboarded Pattern of Native American Allotment. 2012. Indian Land Tenure Foundation. <https://iltf.org/land-issues/issues/>.

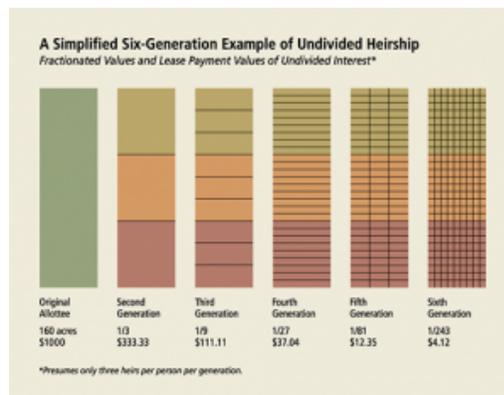


Figure 2 A Simplified Six-Generation Example of Undivided Heirship. 2012. Indian Land Tenure Foundation. <https://iltf.org/land-issues/issues/>.

Works Cited

- “Annual Report on the Issue of Checkerboarding.” Indian Land Tenure Foundation. Accessed May 12, 2022. <https://iltf.org/land-issues/issues/>.
This source explains the process of checkerboarding (dividing large sections of land into smaller areas) through plotted data and diagrams, demonstrating how the Dawes Act hampered agricultural productivity as it created difficulty in processes such as irrigation and ranching. Also explains the generational impacts of checkerboarding.
- Berthrong, Donald J. “Legacies of the Dawes Act: Bureaucrats and Land Thieves at the Cheyenne-Arapaho Agencies of Oklahoma.” *Arizona and the West* 21, no. 4 (1979): 335–54. <http://www.jstor.org/stable/40168884>.
Detailed Case Study on the Cheyenne-Arapaho Tribes of Oklahoma. Useful for specific evidence as well as data used to support how the Dawes Act led to the expropriation of the Native American populace. The information in this article indicated by the title “Bureaucrats and Land Thieves,” is consistent with the scope of my research, which aims to study decreased agricultural productivity caused by the exploitation of the land.
- Carlson, Leonard A. “The Dawes Act and the Decline of Indian Farming.” *The Journal of Economic History* 38, no. 1 (1978): 274–76. <http://www.jstor.org/stable/2119331>.
A research article containing data, case studies, and logical quotes explains the role that the Dawes Act played in reducing Native American incentive to farm. The article also explains how non-Native economic interests by the US governing administration have caused a reduction in Indian agricultural productivity.
- “Catalog of the Public Documents of the 54th Congress, 2nd Session and of All Departments of the United States.” U.S. Government Publishing Office, May 25, 1897. <https://www.govinfo.gov/content/pkg/GOVPUB-GP3-f276716a955aa1e66f1ebccca95d15c6/pdf/GOVPUB-GP3-f276716a955aa1e66f1ebccca95d15c6.pdf>.
Primary source database from 1897, long congress catalog containing public documents published in 1897. Includes complaints filed by Native landholders on the US Bureau of Indian Affairs.
- Cotroneo, Ross R., and Jack Dozier. “A Time of Disintegration: The Coeur d’Alene and the Dawes Act.” *The Western Historical Quarterly* 5, no. 4 (1974): 405–19. <https://doi.org/10.2307/967306>.

Explains the failure of the Dawes Act through the lens of Native American cultural incongruence and ignorance of capitalist systems of property ownership and taxation.

“Dawes Act (1887).” (Feb 8, 2022) National Archives and Records Administration. National Archives and Records Administration. Accessed May 6, 2022.

<https://www.archives.gov/milestone-documents/dawes-act>.

Source from government archive, which contains information on the history of the Dawes Act, it's precedent and historical context, as well as the language of specific sections in the Act.

Fuller, Lauren L. “Alaska Native Claims Settlement Act: Analysis of the Protective Clauses of the Act through a Comparison with the Dawes Act of 1887.” *American Indian Law Review* 4, no. 2 (1976): 269–78. <https://doi.org/10.2307/20067993>.

This source provides information on other possible primary sources including the 1878 Report on the Commissioner of Indian Affairs, as well as the reports by the House Committee in 1880.

Landsman, Gail. “The Ghost Dance and the Policy of Land Allotment.” *American Sociological Review* 44, no. 1 (1979): 162–66. <https://doi.org/10.2307/2094824>.

There are specific sections of data evidence about the loss of tribal land that is useful to extract from this article.

Parman, Donald L., and Lewis Meriam. “Lewis Meriam’s Letters during the Survey of Indian Affairs 1926-1927 (Part I).” *Arizona and the West* 24, no. 3 (1982): 253–80.

<http://www.jstor.org/stable/40169028>.

The Meriam Report of 1927 is a primary source, which contains one of the most comprehensive studies that detailed the failures of the allotment policy. The report blamed the unanticipated consequences of the Dawes Act on the government's insistence on allotting land to tribes that were unprepared for the individual ownership of property.

Perdue, Theda. “The Legacy of Indian Removal.” *The Journal of Southern History* 78, no. 1 (2012): 3–36. <http://www.jstor.org/stable/23247455>.

Journal Article explaining the Governmental bureaucracy that was created by the allotment of private property and how that bureaucracy has led to the exploitation of Native American tribal land through fee patents and tax delinquencies.

Perdue, Sonny. "United States Department of Agriculture." List of Reports and Publications | 2017 Census of Agriculture | USDA/NASS, 2017.

<https://www.nass.usda.gov/Publications/AgCensus/2017/>.

USDA Census contains statistical evidence for the change in agricultural output of native reservations over the timeframe of my research.

"Records of the Bureau of Indian Affairs [BIA]." National Archives and Records Administration. National Archives and Records Administration, 1900.

<https://www.archives.gov/research/guide-fed-records/groups/075.html#75.20.2>.

Primary source from the Bureau of Indian Affairs in 1900. Contains detailed records of surveys in reservations specifically in the [Cantonment Agency and the Oklahoma reservations].

Stuart, Paul. "United States Indian Policy: From the Dawes Act to the American Indian Policy Review Commission." *Social Service Review* 51, no. 3 (1977): 451–63.

<http://www.jstor.org/stable/30015511>.

Article explaining how allotted Native American land was too small and unfit for agriculture to be economically viable, therefore reducing Native American agricultural productivity. Also provides an explanation for how Native Americans were unable to secure credit and were inexperienced in farming. Natives often sold or leased their holdings or lost their lands due to not being able to pay state and federal taxes. Since allotment destroyed tribal sovereignty and created private property, Native Americans were obliged to meet tax obligations.

"The General Allotment Act of 1887 Crippled Native Agriculture for Generations." Native Land Information System. Accessed May 12, 2022.

<https://nativeland.info/blog/uncategorized/the-general-allotment-act-of-1887-crippled-native-agriculture-for-generations/>.

The Native Land Information System plots data extracted from the [2017 USDA Census for Agriculture on American Indian Reservations] into visual graphs, tables, and pie-charts that assists in observing trends over time. Includes information such as "Market value of agricultural products sold," "racial disparity in land distribution," and "leasing of US lands by non-natives."

The United States. Office of Indian Affairs Annual report of the Commissioner of Indian Affairs, for the year 1900, Part I Washington, D.C.: G.P.O., [1900]

<https://digicoll.library.wisc.edu/cgi-bin/History/History-idx?type=header&id=History.AnRep1900p1>.

Primary source containing the Annual report of the Commissioner of Indian Affairs, for the year 1900, published in Washington DC. Contains primary quotes from multiple superintendents on reservations. Includes numerous data for evidence of land loss and land expropriation through federal investigations.

Wayne Moquin and Charles Van Doren, eds., Great Documents in American Indian History (New York: Praeger, 1973), 286. <https://doi.org/10.2307/967206>

A book written by Wayne Moquin and Charles Van Doren, and a vast collection of primary documents between Native Voices and the American Federal government

Wessel, Thomas R. "Agriculture, Indians, and American History." *Agricultural History* 50, no. 1 (1976): 9–20. <http://www.jstor.org/stable/3741903>.

Academic journal article containing statistical information on the productivity of Native American farms prior to allotment in acres cultivated per capita. Useful information for comparative analysis of change over time. The journal also explains how government farmers acted more as clerks and leasing agents rather than farmers and instructors.

Krezenski, Matthew J., "Repercussions of the Dawes Act: Leasing, citizenship, and jurisdiction on the Omaha and Winnebago Reservations, 1887-1896" (2001): 504

<https://digitalcommons.unomaha.edu/cgi/viewcontent.cgi?article=1509&context=studentwork>

Case study on the Omaha Winnebago reservations located in Nebraska, United States. Includes details on leasing and the loss of land exacerbated by the issuing of "fee patent" titles.

Computer Vision: Dominant Color Classification of Product Packaging Across the Globe

By Jiya Gupta

Abstract

Eighty-five percent of buyers say color serves as the primary reason in their decision to buy a product. Companies can stand out by choosing colors unique to those used by their competitors. In this work, I used Google's Cloud Vision API to find the dominant foreground color of 109,129 products across 86 countries and summarized my findings using regression charts.

Introduction

Companies can largely profit by tailoring their packaging to their target customers—namely through color. 85% of customers reported that color was a primary reason in their decision to buy a product. 80% of customers said that color boosted their awareness and recognition of various brands [1].

Some companies currently decide the color of their packaging based on the company's purpose. McDonalds, for example, chooses red because it draws an appetite, while Dairy Milk uses dark purple packaging to draw out a feeling of wealth and luxury while customers savor its rich chocolate. Dove, on the other hand, sells its white soap in a white box to symbolize purity and simplicity [2].

In order to truly stand out and catch the customer's eye, companies might consider choosing colors that both represent its product's purpose and are unique from colors currently used in a target national market [3]. However, very little work has looked at how national markets' most prevalent colors differ from each other.

Existing Work:

- Ozcan and Kandirmaz, 2021 [4] displayed various colored packages to a group of 100 people and observed their resulting purchasing behavior. Results indicate that color's influence on purchases is typically between 80%-100%.

- Richardson, 2020 [5] examined 355 different products across 20 different foods and beverages from Walmart's online grocery service to find the most-used packaging color(s) of each item.
- Singh, 2006 [1] ran multiple experiments to understand color's role in customers' product choice.
- Lai, 2021 [6] conducted four experiments to examine the most effective cake box shape and color combination, as well as the emotions evoked with each box.
- Xin and Hansuebsai, 2007 [7] asked subjects from 7 regions to pick from one of 12 emotions when presented with one of the 214 different tested colors. The purpose was to find the cultural effect on color perception and associated emotions. The factors having the most impact on emotion were chroma and lightness. Influence of the cultural background was found to be rather limited.
- Madden, Hewett, and Roth, 2000 [8] surveyed undergraduate students across several countries and recorded their mean rating/preference of each color.

Goal

In order to differentiate their packaging from current offerings, companies would require a list of the most and least-used packaging colors, which this work aims to provide. With this list, companies can choose colors that aren't so prominent in their respective markets to stand out.

Methods

I used data from Mintel GNPD (global new products database) CSV file with 109,129 different products from 86 countries. Listed products are from the food, drink, household, beauty & personal care, healthcare, and pet industries. Although the file listed multiple attributes for each product, I used the following attributes:

- (1) Record ID, an ID unique to each product.
- (2) Primary Image Thumbnail, a publicly-accessible link to the image of the product packaging
- (3) Market, the name of the country the product was launched in

Note: Some products were launched in multiple countries and may have been altered accordingly. For this work, I consider them as separate products.

Storage

Due to a large amounts of data, I stored the data in Google’s BigQuery database. I created an extra column in the database to store the dominant color for each product as identified by the Google Vision API.

Detection

Google’s Cloud Vision API [9] found the dominant color for each package. The score, found using Computer Vision (a subcategory of Machine Learning), is returned for all detected colors. The score is the prominence of each color respective to the foreground and background. Being part of the background reduces a color’s score. For example, blue is the most prevalent in Figure 1-1, but since it is part of the background, it isn’t labeled as the dominant color.



Dominant colors ranked from the highest to lowest score value:

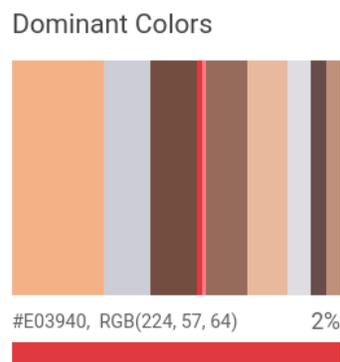


Figure 1-1

Scaling

My program, written in Python, ran in Google's Cloud Functions to find the dominant color for all 109,129 product images. Around ten percent of the time, the API would fail to fetch the dominant color. In such a case, the program would call the API three times until the color is found. If the color is still not found, the program would simply move to the next color.

Because BigQuery doesn't allow multiple programs to update the database at the same time, I ran only two programs in parallel. The program took 200 hours to find the dominant colors and store it in BigQuery for all 109,129 products.

Analysis

I wrote a separate program in Python to pull the market and dominant colors of each product from the database. The program adds each product's dominant color (hex is converted into English form using the webcolors python library) into a multi-layered dictionary organized by country. The number of occurrences of each color for each country is then converted to a percentage:

$$\text{Percent occurrence} = \frac{\text{number of occurrences of color}}{\text{product sample size in country}}$$

All code can be found [here](#).

Results and Discussions:

1. Unique Packaging

The table listed in the appendix contains a list of the detected dominant color for each product organized by country. Companies can observe the most-used packaging colors within a country in the list and accordingly differentiate their packaging. The graphs displayed in the appendix display the most uniquely predictive color (positive or negative) of countries with the largest product sample size using regressions. Dominant color for these countries:

United States: silver

China: silver

Russia: light green

Germany: misty rose

UK: silver

Australia: navy

Italy: Hot pink

France: cyan

India: blue

Japan: silver

2. Market Color Dominance

The data collectively shows that none of the 86 countries has a “prevalent” color. When ignoring the countries with a sample size below 30 packages, the prevalence of the most-used packaging color didn’t exceed 15%. The median prevalence percentage for the most-used color was 6.25%. In general, each country had a large amount of color diversification.

As the product sample size increases for any country, diversification also increases (i.e., the number of colors increases and the percent occurrence for each color decreases).

3. Data Trend

The most-used colors in each of the 86 countries were relatively the same. Figure 1-2 displays the distribution of the most-used colors for every country. Data shows a selected few colors, namely silver, dark slate grey, sienna, indianred, and brown, were the most used in almost every country.

Conclusion

The color of product packaging plays an integral role in the eyes of customers. Using the packaging of 109,129 products across 86 countries, I organized the dominant color of each package by country and analyzed larger countries’ colors using regression. The data displays the most and least-used packaging colors in each country. Companies can accordingly differentiate their product packaging by picking an uncommonly-used color to stand-out their packaging and draw the customer’s attention.

The data also showed two trends: First, no country has a “prevalent color” used in packaging. The most-used color was typically used around only 6% of the time in each country. Colors in the packaging industry across different countries were very diverse. The larger the

sample size of products per country, the more diverse the packing colors of the country. Second, all 86 countries had relatively the same most-used colors. When focusing on just the three most used colors in each country, data shows that six colors (silver, dark slate gray, sienna, rosy brown, and brown) were most used across countries.

In the future, the same process of finding dominant colors of packaging can be used on a per-industry basis within each country for companies to make more informed decisions about their packaging relative to their direct competitors.

Acknowledgements

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Discrete-Time Trajectory Optimization In Space: Low-Thrust Satellites, Orbit Lowering Maneuvers, And Fuel Constraints By Vasanth Gogineni

Abstract

The scarcity of resources in spacecraft makes some missions and maneuvers quite challenging. However, many of these missions have an abundance of another factor: time. Low-thrust spacecraft can follow trajectories that guide them to the destination using very little fuel. Instead of burning sharply to make their orbit smaller, for example, they burn fuel slowly but for a longer time. An algorithm can be developed that allows optimization of thrust profiles of low-thrust satellites around central bodies(planets or stars), minimizing fuel use for the reduction of orbit size around the central body. Using fixed time horizons, the dynamic simultaneous equation algorithm in this paper develops thrust profiles that allow low-thrust trajectory optimization using discrete time. The paper uniquely explores the development and experimentation of this algorithm in Python code for orbit lowering maneuvers, using the GEKKO optimization suite. It was concluded that the thrust profiles demonstrated that the combination of prograde and retrograde burns provided optimum fuel use, satellites further away from central bodies require more fuel, and satellites with lower maximum power require more complex prograde and retrograde maneuvers than higher-power satellites. This translated to the more complex maneuvers requiring more iterations and solution time in the algorithm.

Keywords: Physics and Astronomy; Computational Physics; Trajectory Optimization; Optimal Control; Mechanics

Introduction

Traditionally, spacecraft have had large engines burning fuel at a high rate. However, the increasing length and distance of each space mission with space agencies pushing the boundaries of exploration may increase costs and create a need for a sustainable fuel source. With space colonization and other ambitious goals for the future of space exploration, it is imperative that space exploration does not pollute the Earth, deplete resources, or be infeasible due to a lack of fuel efficiency. Low-thrust engines can provide the answer to this problem, as they are more

efficient and can be fueled by a sustainable source. For example, ion-thrusters have shown fuel efficiencies of over 90%, making the total cost of fuel cheaper and the mission more affordable.¹ Therefore, in order for space missions to be successful, it is vital that low-thrust maneuvers and trajectories minimize the use of fuel to avoid defeating the purpose of efficiency. Trajectory optimization involves finding the best sequence, direction, and magnitude of burns in order to minimize fuel use. This is done by experimenting with thrust profiles to find the one that uses the least fuel.

In the past, a great amount of research has been conducted to find the best method for trajectory optimization. Optimization techniques for spacecraft trajectories include continuous dynamics.² Here, the state variables of the system change instantaneously and not at divided intervals of time. This is opposed to the discrete dynamics used in the algorithm in this paper, which uses a finite number of time points instead. Therefore, the continuous dynamics method is far more computationally demanding, although it is more accurate. For this reason, discrete dynamics are used in the algorithm in this paper.

Given a system with a central star, a low thrust spacecraft can burn fuel to escape a planet it may be orbiting and further control its thrust to reach a certain minimum distance to the star using the least fuel possible. This fairly complex problem needs to be broken down in order to build an algorithm capable of handling several similar situations in space.

First, the orbital mechanics were simulated using VPython,³ a simulation tool in Python. Next, using an optimization tool named GEKKO,⁴ the equations verified and applied in the simulation were then adapted to suit the fuel-constrained optimization problem. The new GEKKO model was manipulated to handle various satellites and planets as needed and was finally used to minimize fuel use.⁴ With the rapid growth of the Python programming language, this algorithm in Python code is unique and relevant due to the growing need for wider access to optimization tools to calculate optimum satellite ephemeris around Earth or other parameters. This complex system needs to consider the fuel constraints of satellites, the trajectory of satellites, planet positions, and other factors. This algorithm, thus, provides a quick yet rigorous method of estimating optimum thrust profiles to plan a space mission for, for example, an electric-propulsion spacecraft.

The algorithm used in this paper is a dynamic optimization algorithm that uses discrete time for trajectory optimization. It involves simultaneous equations that define the orbital mechanics. This

paper uniquely and specifically examines a new discrete time and simultaneous differential equation trajectory optimization algorithm in terms of orbit-lowering maneuvers.

Methods

Problem Statement

I. The first part of the problem involves defining the equations of orbital mechanics to later derive equations suitable for the optimization.

$$F = \frac{Gm_1m_2}{R^2}$$

$$p = mv$$

$$\frac{dr_x}{dt} = p_x/m_2, \frac{dr_y}{dt} = p_y/m_2$$

$$\frac{dp_x}{dt} = F_x + T_x, \frac{dp_y}{dt} = F_y + T_y$$

Simulating this situation in VPython for all planets centered around the sun,³ we can verify the functionality of these basic equations as shown in Figure 1.

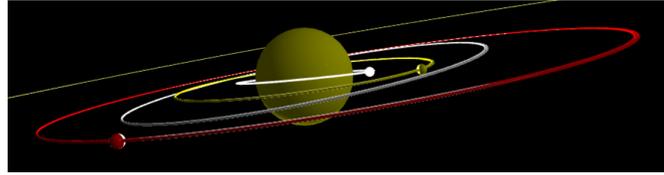


Figure 1. Image of the simulation of the orbital mechanics of all planets and the Sun in VPython. The above screenshot of the working simulation allows us to derive further equations for discrete time.

II. The equations for the mathematical optimization problem can now be derived in order to function simultaneously in discretized time.

Splitting F into components for a mathematical simulation:

$$\vec{F} = \frac{-Gm_1m_2}{R^3} \times \vec{r} \rightarrow$$

$$\vec{F}_x = \frac{-Gm_1m_2}{R^3} \times rx, \vec{F}_y = \frac{-Gm_1m_2}{R^3} \times ry, \vec{F}_z = \frac{-Gm_1m_2}{R^3} \times rz$$

$$\text{Let } \mu = Gm_1$$

$$\text{If so, } \mu = 2.959 \times 10^{-4} \text{ AU}^3/\text{day}^2$$

$$\text{Now, } \vec{F} = \frac{-Gm_1m_2}{R^3} \times rx$$

Converting force to acceleration:

$$ax = \frac{Fx}{m_2} = \frac{-\mu}{R^3} \times rx, ay = \frac{Fy}{m_2} = \frac{-\mu}{R^3} \times ry, az = \frac{Fz}{m_2} = \frac{-\mu}{R^3} \times rz$$

T is defined as the ratio of engine thrust to mass

$$|v| = \sqrt{(vx^2 + vy^2 + vz^2)}$$

$$T_x = -T \times \frac{v_x}{|v|}, T_y = -T \times \frac{v_y}{|v|}, T_z = -T \times \frac{v_z}{|v|}$$

Therefore, the governing differential equations are as follows:

$$\frac{d}{dt} vx = ax, \frac{d}{dt} vy = ay, \frac{d}{dt} vz = az$$

$$\frac{d}{dt} rx = vx, \frac{d}{dt} ry = vy, \frac{d}{dt} rz = vz$$

by definition.

III. The **objective function** needs to integrate the thrust with respect to time to obtain the fuel use. This fuel use needs to be minimized for making this low-thrust fuel optimization algorithm. The thrust here is taken as a function of time.

$$\min \int_0^t T(t) dt$$

IV. Constants and initial state

$$r_x(0) = -25182934840.587124$$

$$r_y(0) = 132794579028.3616$$

$$p_x(0) = m_1 \times -29802.266813363603$$

$$p_y(0) = m_1 \times -4860.043346427637$$

$$m_1 = 1.989 \times 10^{30} \text{ [MASS OF SUN]}$$

$$m_2 = 500$$

$$T_{max} = 2 \times 10^{-5}$$

IV. The **constraints** of the algorithm include the maximum magnitude of thrust and the final orbit radius.

T = Manipulated instantaneous thrust

R = distance of the satellite from the barycenter

f = Final time point

x = required radius of the orbit around the central body

T_{max} = magnitude of maximum instantaneous thrust delivered by the satellite

t = time

$$R(t) = \sqrt{(r_x)^2 + (r_y)^2 + (r_z)^2}$$

$$R(f) < x$$

$$|T| < T_{max}$$

Assumptions

Throughout the problem statement, it has been assumed that certain conditions are true for the simplification of the problem and due to the large scale of the solar system.

A. It must be noted that a key assumption in this algorithm is the proportionality of thrust and fuel use. They are considered proportional due to the high efficiency of low-thrust engines and because the energy loss due to mass and other factors is significantly lower compared to the values for larger propulsion systems.

B. Another important assumption to simplify the problem is that the sun is at the barycenter. This is assumed to be true due to the relative closeness of the sun to the barycenter considering the scale of the solar system.

Computational Experiment Setup

The mathematical form of the optimization problem in the previous section is quite complex to convert to python code to use the GEKKO optimization package.⁴ Therefore, we can simplify the conversion by first defining an orbit in GEKKO and then introducing a test case for the optimization problem.⁴ The Python code for the simulations and optimization algorithms can be found in this link:

<https://github.com/Vasanth-Gogineni/Discrete-Time-Trajectory-Optimization-In-Space>.

I. Defining and simulating an orbit

The solver is tuned to sequential simulation independent of a manipulated variable. The time in the GEKKO model is discretized and a time horizon of 1 year is defined.⁴ The timescale is

initialized to 1/1/2010. Using the Skyfield API file ‘de421.bsp’ to obtain ephemeris data and state vectors,⁵ the initial conditions of the orbit are defined.

We can set the number of nodes in each time segment to obtain greater precision. Then, implementing only the ‘governing differential equations’ mentioned in the previous section, we have a system of equations that simulate the gravitational effect of the Sun on the Earth, producing the orbit shown in Figure 2.

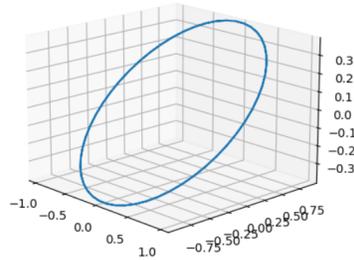


Figure 2. The graph shows the trajectory or orbit of a satellite defined and simulated in GEKKO.

However, underlying intermediate equations are needed to define a_x , a_y , and a_z . These intermediate equations are essentially equations that dynamically assign values to explicitly defined intermediate variables using updated values after every iteration to reduce the problem complexity. The variables a_x , a_y , and a_z should be intermediate variables dynamically assigned values using the equations in the Problem Statement. However, these require R also to be defined, and so the $R(t)$ equation should also be an intermediate.

II. Introducing objective function for optimization in GEKKO.⁴

Applying the structure of the algorithm from the orbit simulation, the solver is tuned to dynamic simultaneous equation solving for control applications. This now allows the manipulated variable(MV), fuel/thrust(used interchangeably), to be introduced. The MV has been constrained with a maximum and minimum thrust suitable for low-thrust engines($2 \cdot 10^5$ AU/day²). The lower bound is negated to provide reverse thrust.

The GEKKO model required the objective function to be defined in a split form.⁴ With integrated thrust set as a variable, its differential equation assigned it the absolute value of the instantaneous thrust to signify fuel use. Next, a zero-filled array with its last element with value ‘1’ was pointwise multiplied with the integrated thrust function and summed to extract the value of the final and total fuel used. This optimized fuel value and trajectory were plotted using MATPLOTLIB.⁶

To verify the functionality of the trajectory optimization in the algorithm, an experiment with the asteroid Ceres' initial state vectors from NASA's Horizons system and the sun as the central body was performed,⁷ as seen in Figures 3-5. The final orbit radius was set to 1.8 AU.

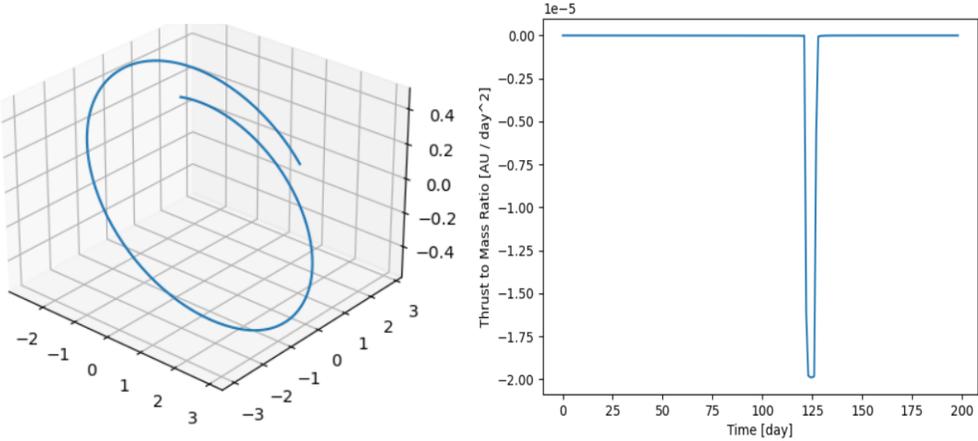


Figure 3 and Figure 4. Figure 3 on the left shows the trajectory of the satellite departing from Ceres. Figure 4 on the right shows the thrust profile or the fuel use with time for the optimized trajectory.

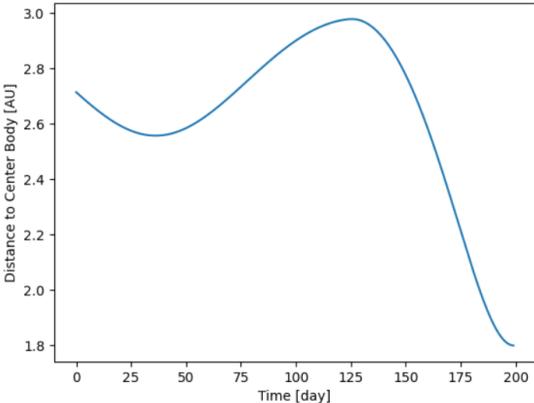


Figure 5. The figure shows the distance to the Sun as time progresses. Note that the final distance in the graph is 1.8 AU.

Here, to change the orbit, R (distance between central body and planet) in Figure 5 was given an inequality constraint to define the radius of the new orbit. Overall, the introduction of the optimization required a complex definition of the objective function and constraints.

Graphs

There are 3 types of graphs produced by the algorithm using MATPLOTLIB,⁶ as seen in Figures 3-5. The first graph is a 3D graph showing the exact trajectory of the satellite around the Sun, which is located at (0,0,0). The second graph shows the thrust profile or the thrust to mass ratio throughout the time horizon, which is eventually integrated to find the total thrust or fuel use. The third graph shows the position relative to or the distance from the Sun. The 3 graphs will be identified as A, B, and C respectively in the set of graphs for an experiment.

Experiment

The optimization algorithm was first tested to ensure its accuracy. With no thrust acting in Figure 2, the orbit and its inclination is plotted in a 3-dimensional graph. The orbit is elliptical and verifies the accuracy of the algorithm in simulating ephemeris. The plot and data showed that the elliptical orbit makes the Earth move a mean distance of around 1 AU away from the barycenter, which is true by definition of the 'AU'.

The optimization algorithm will consider the following test cases:

- I. Different satellites around the Sun
- II. Effect of maximum thrust on thrust profile
- III. Effect of prograde and retrograde burns

I. Different Satellites around the Sun(Sun as a central body)

In this experiment, the central body is the Sun. Satellites originating from different planets are tested, assuming the satellite has left the planet's gravitational field already. The satellite and Sun system is then used with the optimization algorithm to reduce the orbit size of the satellite around the Sun.

For this experiment, the algorithm has been set up with 0.7 AU as the maximum final displacement from the sun. Since an orbit with average radius 0.7 AU is larger than or similar to that of Mercury and Venus, only satellites or spacecraft originating from Earth, Mars, Jupiter, and Saturn are considered to test a consistent type of maneuver(larger to smaller orbit).

An important parameter to note is the absolute value of thrust available. The value is 2×10^{-5} AU.

First, a system with the Sun and a satellite originating from the earth was tested as shown in Figures 1A, 1B, and 1C.

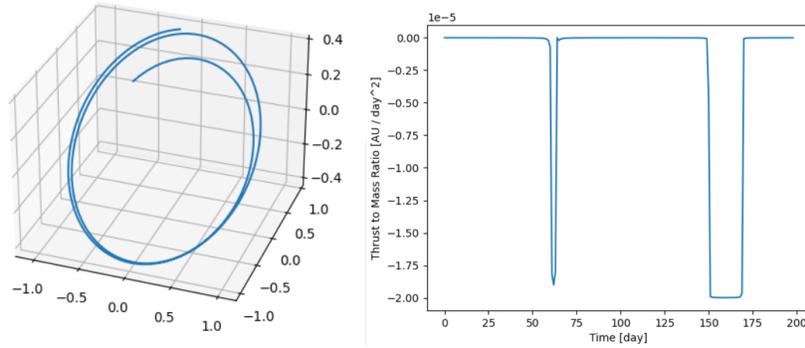


Figure 1A and Figure 1B. Figure 1A(left) shows the trajectory of the satellite departing from Earth in Experiment 1. Figure 1B(right) shows the thrust profile of the satellite departing from Earth in Experiment 1.

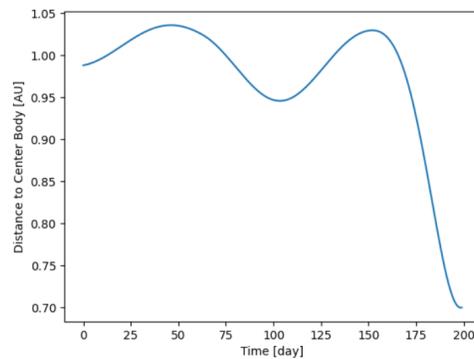


Figure 1C. Figure 1C shows the distance to the Sun of the satellite departing from Earth in Experiment 1.

Further exploring, a system with the Sun and satellite originating from Mars can be tested as in Figure 2A, 2B, and 2C. The initial state vectors can be adjusted using the Skyfield API to test satellites from Jupiter and Saturn.⁵

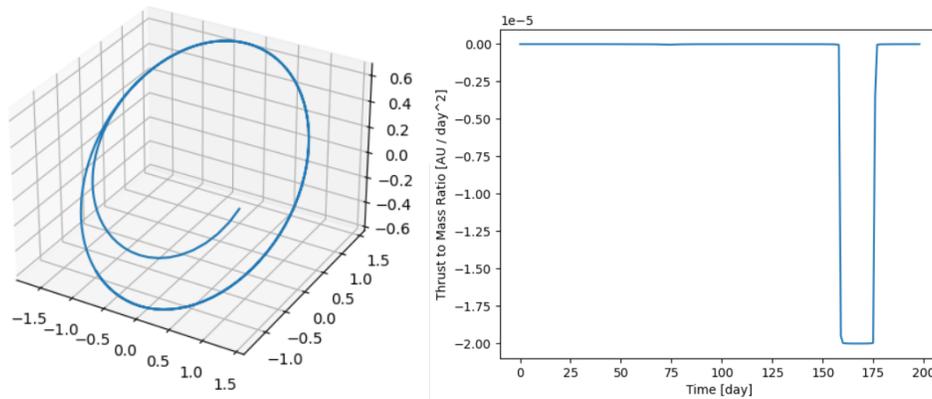


Figure 2A and Figure 2B. Figure 2A(left) shows the trajectory of the satellite departing from Mars in Experiment 1. Figure 2B(right) shows the thrust profile of the satellite departing from Mars in Experiment 1.

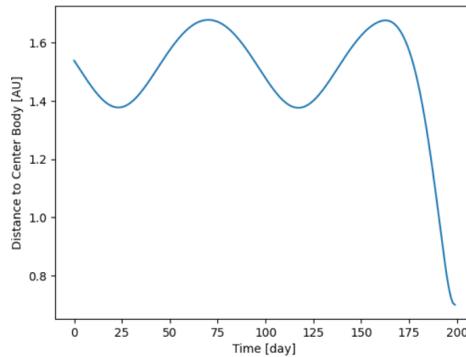


Figure 2C. Figure 2C shows the distance to the Sun of the satellite departing from Mars in Experiment 1.

Figures 3A, 3B, and 3C show a Jupiter Satellite and Sun system.

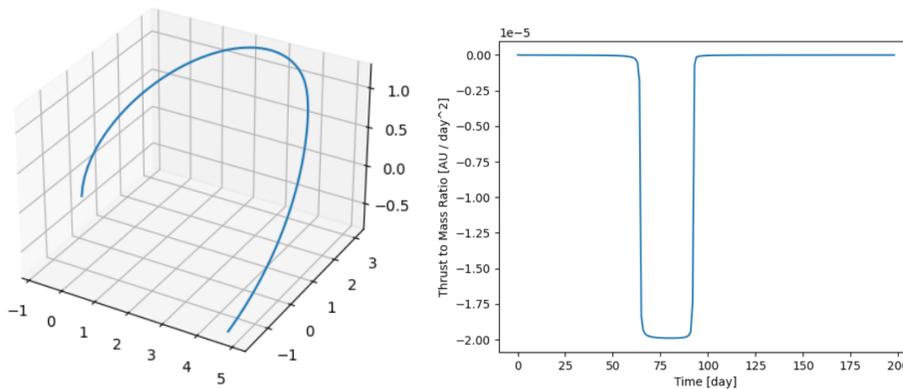


Figure 3A and Figure 3B. Figure 3A(left) shows the trajectory of the satellite departing from Jupiter in Experiment 1. Figure 3B(right) shows the thrust profile of the satellite departing from Jupiter in Experiment 1.

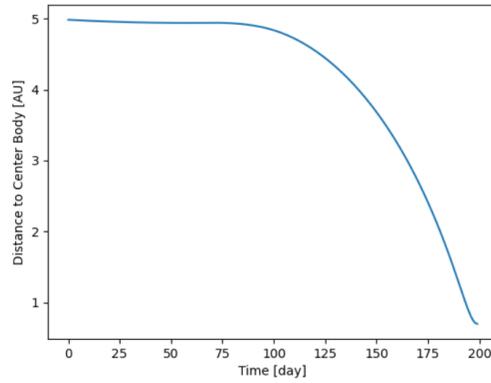


Figure 3C. Figure 3C shows the distance to the Sun of the satellite departing from Jupiter in Experiment 1.

Figures 4A, 4B, and 4C show a Saturn Satellite and Sun system.

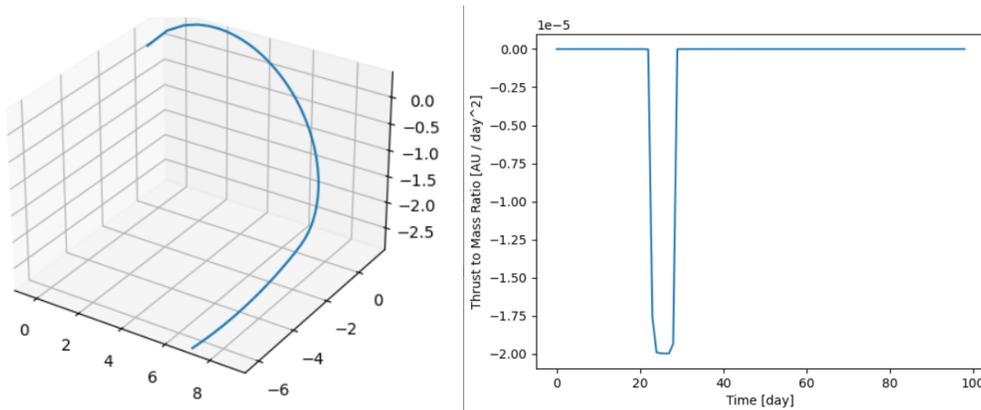


Figure 4A and Figure 4B. Figure 4A(left) shows the trajectory of the satellite departing from Saturn in Experiment 1. Figure 4B(right) shows the thrust profile of the satellite departing from Saturn in Experiment 1.

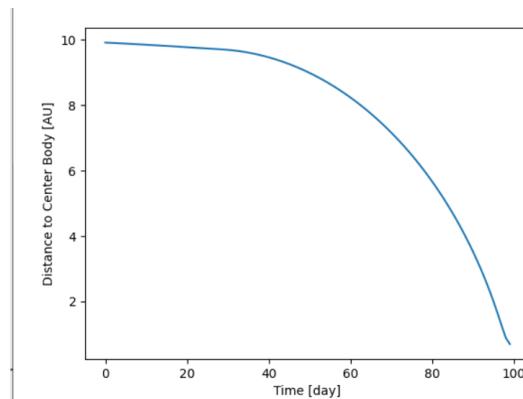


Figure 4C. Figure 4C shows the distance to the Sun of the satellite departing from Saturn in Experiment 1.

The results of the experiment from the solver are summarized in Table 1.

Table 1. Table 1 below summarizes the results from the solver for Experiment 1. It shows the solution time, total thrust used, and number of iterations.

Data Table for Experiment 1

Planet from which satellite originated	Solution Time(secs)	Objective/Total thrust (AU/day ²)	No. of iterations
Earth	95.5246000000006	1.607075469841769E-003	364
Mars	61.0000999999975	2.496310652516179E-003	241
Jupiter	8.30809999999838	4.060410390841822E-003	35
Saturn	272.912699999986	3.386803406157031E-003	1972

II. Effect of maximum thrust on thrust profile

The next experiment involved testing the effect of the maximum magnitude of instantaneous thrust (T_{max}) on the optimum thrust profile, the objective function (minimized thrust), solution time, and the number of iterations to reach the solution.

The parameters used included a time horizon of 3 years and 200 total time points within that time horizon. The maximum magnitude of instantaneous thrust values that were tested were $1 \cdot 10^{-5} \text{AU/day}^2$, $2 \cdot 10^{-5} \text{AU/day}^2$, $3 \cdot 10^{-5} \text{AU/day}^2$, and $4 \cdot 10^{-5} \text{AU/day}^2$. The planet of origin of the satellite was kept constant as Earth with the desired orbit radius as 0.3 AU.

The graphs for $T_{max} = 1 \cdot 10^{-5} \text{AU/day}^2$ are shown in Figures 5A, 5B, and 5C.

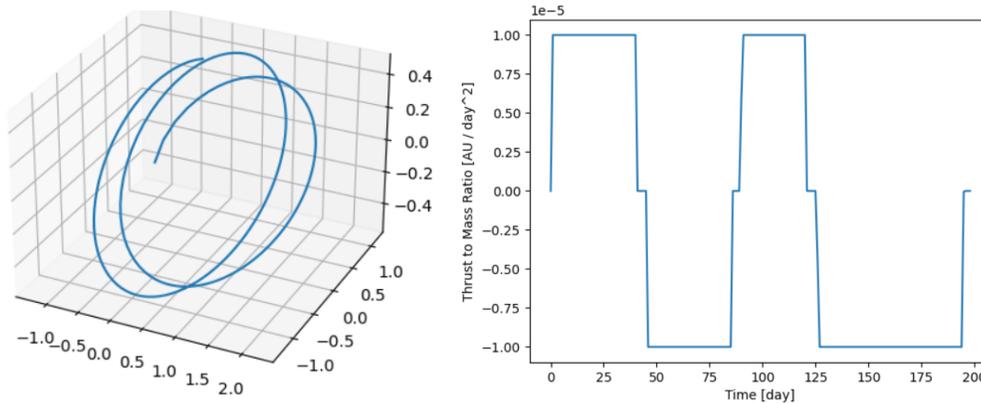


Figure 5A and Figure 5B. Figure 5A(left) shows the trajectory of the satellite with $T_{max}=1*10^{-5}$ in Experiment 2. Figure 5B(right) shows the thrust profile of the satellite with $T_{max}=1*10^{-5}$ in Experiment 2.

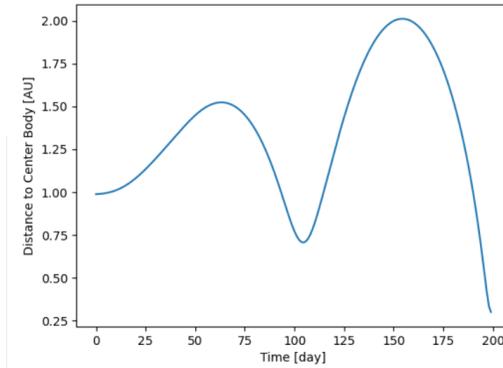


Figure 5C. Figure 5C shows the distance to the Sun of the satellite with $T_{max}=1*10^{-5}$ in Experiment 2.

The graphs for $T_{max}=2*10^{-5} \text{ AU/day}^2$ are shown in Figures 6A, 6B, and 6C.

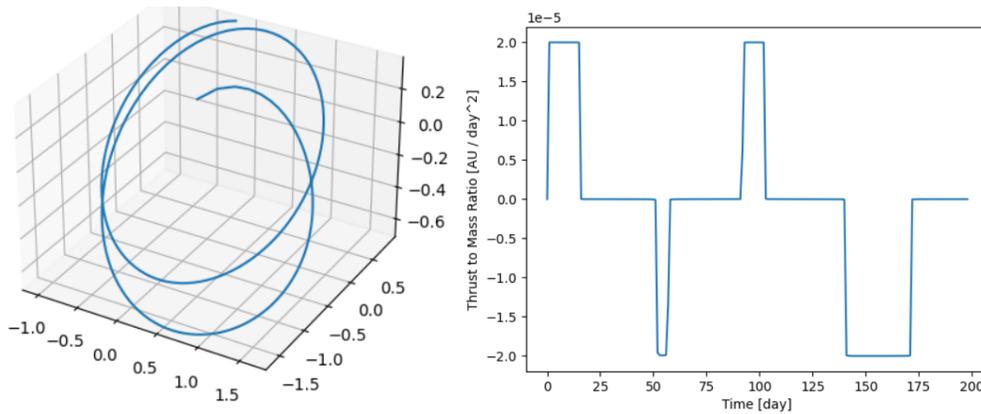


Figure 6A and Figure 6B. Figure 6A(left) shows the trajectory of the satellite with $T_{max}=2*10^{-5}$ in Experiment 2. Figure 6B(right) shows the thrust profile of the satellite with $T_{max}=2*10^{-5}$ in Experiment 2.

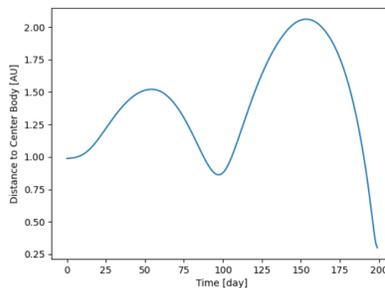


Figure 6C. Figure 6C shows the distance to the Sun of the satellite with $T_{max}=2*10^{-5}$ in Experiment 2.

The graphs for $T_{max}=3*10^{-5}AU/day^2$ are shown in Figures 7A, 7B, and 7C.

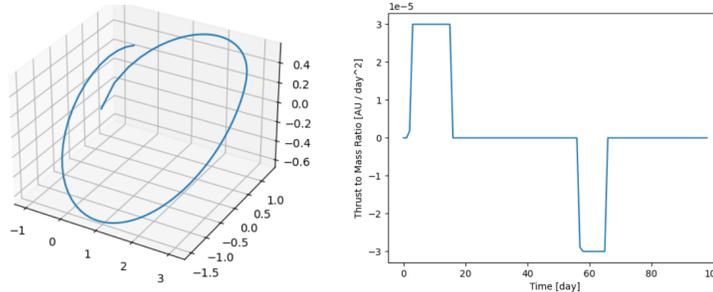


Figure 7A and Figure 7B. Figure 7A(left) shows the trajectory of the satellite with $T_{max}=3*10^{-5}$ in Experiment 2. Figure 7B(right) shows the thrust profile of the satellite with $T_{max}=3*10^{-5}$ in Experiment 2.

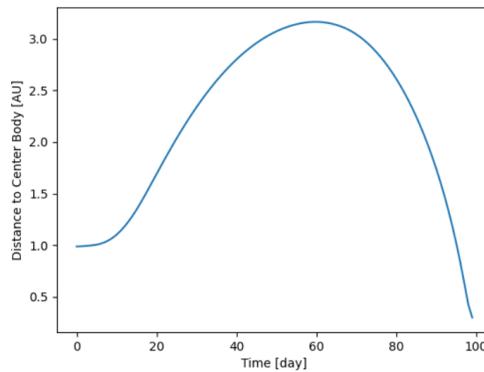


Figure 7C. Figure 7C shows the distance to the Sun of the satellite with $T_{max}=3*10^{-5}$ in Experiment 2.

The graphs for $T_{max}=4*10^{-5}AU/day^2$ are shown in Figures 8A, 8B, and 8C.

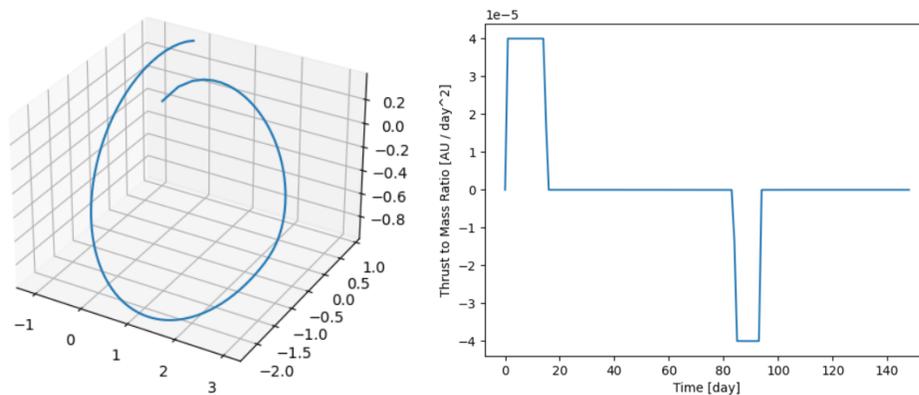


Figure 8A and Figure 8B. Figure 8A(left) shows the trajectory of the satellite with $T_{max}=4*10^{-5}$ in Experiment 2. Figure 8B(right) shows the thrust profile of the satellite with $T_{max}=4*10^{-5}$ in Experiment 2.

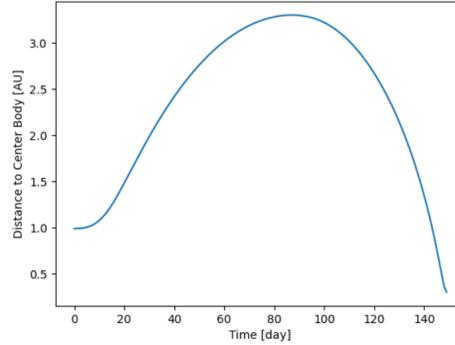


Figure 8C. Figure 8C shows the distance to the Sun of the satellite with $T_{max}=4*10^{-5}$ in Experiment 2.

The results from the solver are summarized in Table 2.

Table 2. Table 2 below summarizes the results from the solver for Experiment 2. It shows the solution time, total thrust used, and number of iterations.

Data Table for Experiment 2

T_{max}	Solution Time(secs)	Objective/Total thrust (AU/day ²)	No. of iterations
$1*10^{-5}$	269.367300000013	9.838975205602179E-003	1096
$2*10^{-5}$	109.0267999999992	6.799494899789606E-003	425
$3*10^{-5}$	206.8282999999994	7.287932388867752E-003	1535
$4*10^{-5}$	21.8685000000114	6.968041141756977E-003	122

III. Effect of prograde and retrograde

Considering an Earth Satellite and Sun system with a satellite departing from Earth at Earth's initial position relative to the barycenter, the trajectory of the satellite to an orbit around the Sun can be fuel-optimized. By constraining the final displacement(R) from the barycenter to be the radius of the orbit, the algorithm produces an optimum thrust profile using 200 time points over a time horizon of 2 years. The value of 'R' is set to 0.2 AU. The result of this experiment is shown in Figures 9A, 9B, and 9C.

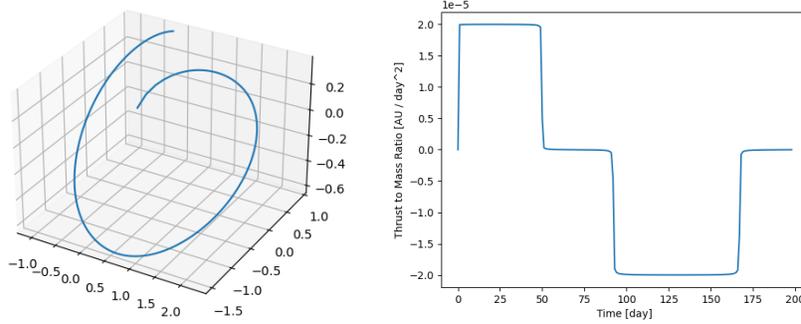


Figure 9A and Figure 9B. Figure 9A(left) shows the trajectory of the satellite departing from Earth and using prograde and retrograde burns in Experiment 3. Figure 9B(right) shows the thrust profile of the satellite departing from Earth and using prograde and retrograde burns in Experiment 3.

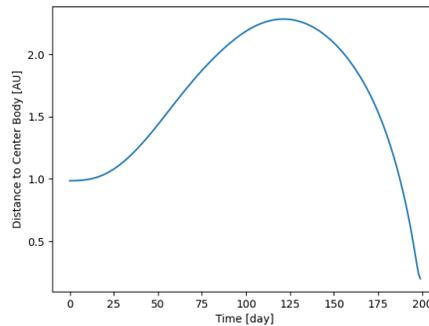


Figure 9C. Figure 9C shows the distance to the Sun of the satellite departing from Earth and using prograde and retrograde burns in Experiment 3.

The thrust to mass ratio-time graph in Figure 9B shows the thrust profile of the satellite described above. By integrating the thrust shown here, the solver calculates a thrust value.

Experimenting with various such thrust profiles, the solver has singled out the above fuel-minimized profile.

Results and Discussion

The graph in Figure 9A shows the trajectory of the satellite to the new orbit. The problem setup in the script is a satellite that just left earth that needs to get within 0.2 AU of the sun. The solver is able to do this by first burning prograde to actually move away from the sun initially. Once the satellite is farther away from the sun, relative to where it started on earth, it is moving

much slower. Therefore the second thrust maneuver, which is retrograde, is more efficient. The result is the satellite makes a pass within 0.2 AU of the sun at the end of the 2 year time horizon. It can be verified from this experiment that a prograde burn increases the velocity of the satellite in orbit, causing an increase in orbit radius. On the other hand, a retrograde burn slows down the satellite, causing the Sun's gravity to pull the satellite inwards to a smaller orbit.

It can also be concluded that a prograde burn to increase orbit size increases the efficiency of the maneuver. A continuous retrograde burn would reduce the speed but would require continuous fuel use. However, a prolonged prograde burn increases the radius of the orbit.

$$F = \frac{mv^2}{r}$$

The centripetal force equation above shows that the gravitational force on the satellite reduces as the orbit radius increases, as $F \propto 1/r$.⁸ This also means the velocity of the satellite in the orbit reduces, as $F \propto v^2$. Therefore, the prograde burn assists the reduction of velocity required to reduce the orbit size. This more efficient reduction of speed assisted by Earth's gravity makes the retrograde burn more effective, as less speed needs to be reduced to reduce the orbit size. The theory and discussion described above in this subsection will be used in the following discussions.

Discussion of Experiment 1

As can be seen in Table 1, the fuel use or total thrust increases continuously as we go from closer to distant planets from the Sun. This is quite intuitive because a satellite further away from the Sun would be expected to use more fuel to reach an orbit closer to the Sun. In the following discussion, the data row for Saturn is anomalous as discussed later in this section. However, from the thrust profile graphs, it is evident that the duration of the burn has increased from the Earth to the Jupiter graphs. This indicates a greater fuel use or greater thrust required for satellites further from the Sun to reduce the speed to a value that allows the gravity of the Sun to pull the satellite into the desired orbit. The greater thrust is required for satellites further away from the Sun because the satellite needs to reduce its speed by a greater amount to reach the new orbit within the time horizon, as the gravitational force would be greater with a lower speed. The greater force would pull the slowed satellite toward the new orbit faster than satellites that burned retrograde for less time.

The first 2 sets of graphs(Earth and Mars) show a movement away from and toward the Sun in the distance to the Sun graphs. The next 2 sets of graphs(Jupiter and Saturn) show a continuous movement towards the Sun. These 2 types of graphs indicate that the solution or trajectory is simpler for the graphs for Earth satellites and Mars satellites. This explains why the number of iterations required and solution time is greater for the satellites closer to the Sun(Earth and Mars). However, they all show retrograde burns, indicating the reduction of speed to use a gravity assist from the Sun towards the new orbit.

However, the data row for Saturn is anomalous as it shows a lower total thrust, but greater solution time, and iterations compared to Jupiter. This breaks the trend and is mainly due to the alteration and restriction of the time horizon and time points, which was done due to the infeasibilities of the problem setup for Saturn for 2000 maximum iterations and 200 time points. This restricted problem setup forced the solver to use a greater total thrust in order to reduce the speed faster to achieve the required orbit within the time horizon. It can be predicted, however, that a satellite from Saturn too would take more fuel than from a closer planet, such as Jupiter. This is because the graphs are in the same shape and follow the same type of trajectory and fuel use as the other planets. Therefore, it can be expected that a satellite from Saturn would also follow the trend.

Discussion of Experiment 2

Experiment 2 examined the effect of T_{\max} on the optimum thrust profile. From Table 2, it is evident that all values of T_{\max} tested yielded values of the objective function of the same order of magnitude. Therefore, there is not much of a clear observation from the objective function values only. The graphs must also be considered. However, it should be noted that the objective function value for $T_{\max}=1*10^{-5}$ is greater than that of the other T_{\max} values. This indicates that an extremely low thrust reduces the efficiency of the maneuver noticeably in terms of fuel use. Further support is provided by the fact that the other objective function outputs in the table are all roughly the same, around the value $7*10^{-3}$. This means extremely low thrust burns may also be less efficient compared to moderately low-thrust burns for orbit-change maneuvers(inferred for larger to smaller orbit only from the scope of this experiment).

Note, again, that $3*10^{-5}$ is an anomalous data row due to the infeasibilities described in the previous subsection. However, as described in the previous subsection, it can be predicted to

follow the same trend without the infeasibilities. The 4×10^{-5} data was tested with 140 time points to reduce infeasibilities, so the objective function may not be accurate. However, the graphs produced provide an accurate shape to demonstrate the basic maneuver, giving a trend described below.

Moving onto the graphs, there is a noticeable trend or difference between lower thrust satellites and higher thrust satellites. Two general groups are identified. Each group's graphs follow the same pattern of trajectory, thrust profile, and displacement from the Sun.

Group 1: Figure 5A and Figure 6A are grouped together since they use 2 prograde and 2 retrograde burns to achieve the new orbit, as shown by Figure 5B and Figure 6B. This is verified from Figure 5C and 6C respectively.

Group 2: Figure 7A and Figure 8A are grouped together since they each use 1 prograde and 1 retrograde burn to achieve the new orbit, as shown by Figure 7B and Figure 8B. This is verified from Figure 7C and 8C respectively.

The Group 1 maneuvers involve 2 revolutions around the sun, during which the satellite used a first prograde burn to raise its orbit as in the trajectory graphs. This effectively reduces the speed of the satellite automatically due to the relation between orbit radius and velocity discussed in the Discussion of Experiment 3. The subsequent retrograde burn further reduces the orbital velocity till a point where Sun's gravity starts pulling the satellite towards it. This is repeated again in the second revolution, reducing the speed until the Sun's gravity pulls the satellite into the orbit of the required radius.

The Group 2 maneuvers use only 1 revolution around the Sun. In this revolution, they burn prograde followed by retrograde for reasons mentioned in the previous paragraph and in the Discussion of Experiment 3. However, they only burn prograde and retrograde once. This difference can be attributed to the fact that the lower-thrust Group 1 satellites cannot produce enough thrust in the same period of time as higher-thrust Group 2 satellites. This explains why Group 1 satellites needed 2 revolutions with 2 retrograde and prograde burns in order to take the Sun's assistance twice. The higher-thrust satellites could produce enough thrust to complete the maneuver within 1 revolution, as they could reduce the speed by the required amount till the Sun pulled the satellite into the required orbit. The lower-thrust satellites needed an extra gravity assist.

In each of the groups, however, the lower T_{\max} values have a longer solution time and take more iterations to reach the desired orbit. This can be attributed to the fact that, for the same pattern or type of trajectory (the differentiator between the groups), the higher T_{\max} satellites would be able to burn fuel to achieve the thrust required in a shorter period of time. Therefore, the number of iterations required in the solver, and hence the time taken to complete the maneuver, would all be lesser.

It is important not to confuse the time horizon (number of days) with the time points. The time points are the number of points used to divide the time horizon for the solver to calculate positions and equations periodically in every iteration.

Conclusion

By testing an algorithm for trajectory optimization for fuel use in discrete time, it can be concluded that maneuvers using a prograde and a retrograde burn optimize fuel use for a maneuver that reduces the radius of the satellite orbit around a massive central body. It can also be concluded that the further away a satellite is from the Sun, the greater total thrust is required during a retrograde burn to use the gravity assist of the Sun to bring the satellite to a smaller, desired orbit. Moreover, from Experiment 2, it is evident that lower thrust satellites follow a different optimized thrust profile due to their inability to reduce or increase speed as quickly as higher thrust satellites. The optimized thrust profiles involve the use of gravity assists from the central body.

In terms of the algorithm performance and solution parameters, the simpler or less varied maneuvers used a lower number of iterations and solution time. These simpler maneuvers were characteristic of higher thrust satellites and satellites further away from the central body, as evident from the 2 types of graphs in Experiment 1 and 2.

The research can be used to study orbit lowering maneuvers, the characteristics of discrete optimization in terms of astrodynamics applications, and as a tool to generate optimum thrust profiles. The algorithm serves as the basis and has the potential to determine the time feasibility for satellites aiming to be sent on a long-term or short-term mission towards the Sun, or another central body. It provides easy determination of the feasibility of missions in terms of fuel availability and provides access to simulating and optimizing a wide range of situations by changing the algorithm parameters and variables.

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Government Policy: Does It Have a Major Effect on Economic Growth? By Tanmay Jha

Introduction

The extent of government regulation and its relation to the economy has been one of the most debated topics in American history. Every political group, from Alexander Hamilton's Federalists and Thomas Jefferson's Republicans, to our current Democrats and Republicans, has had their own unique viewpoint on the issue. Some argue in favor of the Laissez-Faire concept, stating that a low level of government regulation is optimal for economic growth, while others believe that a high amount of government regulation helps bolster the economic growth of a nation. However, if we look at various sectors of government policy and their historic effects on economic growth, it appears that neither of these viewpoints is entirely accurate. The data seem to show that for much of American history, most aspects of government policy have had little to no effect on the economic rate of growth.

Tariffs

Employed with the intention of driving consumers towards domestically produced products, tariffs are one of the most direct ways that a government can impact the economy.

Tariffs have had an expansive history in America, with the Tariff of 1789 being the first major act passed by the United States government after the ratification of the constitution. This act was intended to protect America's growing manufacturing sector, and to raise money for the American federal government. It levied a \$0.50 per ton charge on foreign goods, while American manufacturers were charged \$0.06. Although controversial at first, the Tariff of 1789 set a precedent for future tariffs, which provided the federal government with large amounts of revenue in the early and mid 1800s, and successfully safeguarded American manufacturers.⁴⁴

The turn of the century, however, saw the American government gain other avenues of obtaining revenue, and the rapid industrial expansion that occurred during the late 1800s resulted in the American industry growing strong enough to compete with foreign entities. As a consequence, the tariff fell out of use until the presidency of Herbert Hoover, who created the Hawley-Smoot tariff as a result of the Stock Market crash of 1929.

⁴⁴ A Brief History of Tariffs in the USA and the Dangers of Their Use Today, Tyler Halloran, Fordham.edu, March, 2019.

Signed into action in 1930, the Hawley-Smoot tariff was created with the purpose of protecting American farmers and other industries from foreign competition by raising over 900 import tariffs by 40-50%. As stated by many economists at the time, it massively backfired because many United States trade partners also enacted tariffs against American goods, freezing international trade, increasing food prices, and sinking the economy deeper into the Great Depression.⁴⁵

Naturally, due to the seemingly disastrous economic impact of the Hawley-Smoot tariff, many economists convey the belief that government mandated tariffs can have a catastrophic effect on economic growth. This belief, although seeming to be logically sound, is actually not supported by data. Figure 1, which compares the real GDP of the United States over the time as opposed to the average tariff rates in the United States history, reveals that although tariff rates have shown massive fluctuations throughout American History, real GDP has grown at a steady rate that seems to be independent of high tariff rates.

For example, the Hawley Smoot tariff is shown in the Figure as a huge spike in the average tariff rate around 1930, but at the same time period, the growth of real GDP does not seem to experience a major decline, with the slight decrease being a product of the Great Depression. Conversely, after World War II the American government adopted a transition away from major tariffs, which is represented in the Figure, as a sharp decline in tariff rates after the 1940s is made apparent. And yet once more, this large fluctuation in tariff rates seems to have no impact on the growth of Real GDP, which continues its steady growth throughout the 50s and 60s.

Hence, as represented by this data, despite being one of the most prevalent forms of government policy throughout American History, tariff rates don't appear to have any lasting impact on the economic rate of growth.

Taxes

One of the biggest and most controversial forms of government policy is taxation. Reeling from the effects of over taxation from an unjust government, the early American government only charged excise taxes. Income taxes were first introduced in the United States

⁴⁵ What Hawley-Smoot Act Can Teach Protectionists Today, Kimberly Amadeo, The Balance, March 2021

during the Civil War in order to finance the Union army, and were later made permanent with the 16th amendment in 1913.

The effects of taxation on the economic rate of growth are heavily debated, with some arguing that an increase in taxes helps the government gain more revenue with which they can invest in certain industries in order to improve the economy, while others state that tax cuts are more beneficial towards economic growth, as lower tax rates allow individuals to have more spending power, which in turn bolsters the economic rate of growth.⁴⁶

However Figure 2, which displays total tax revenue as a percentage of GDP over time, and compares it to a graph of real GDP over time, shows how neither of these theories appear to be backed by data. When observing the tax revenue graph, we can discern an obvious spike in tax revenue during the 1910s, with the passage of the 16th amendment, but this spike is not reflected in the graph of real GDP over time, which appears to grow at the same, steady rate. This trend appears to remain consistent throughout the next time period covered by the graphs, with federal tax revenue experiencing significant spikes and downturns, and real GDP seems to persist in its steady rate of growth, independent of the changes in tax policy.

Therefore, federal tax policy, although being one of the most hotly debated topics throughout American history, does not seem to have a monumental effect on the economic rate of growth.

Foreign Policy

Turbulent and ever changing are the first words that come to mind when describing American foreign policy. Contrary to its modern day reputation as the “policeman” of the world, the American republic began with a far more solitary mindset. George Washington was famously opposed to the idea of “foreign entanglements”, and his beliefs were reflected in his support of the Neutrality Act of 1794 and the Jay Treaty of 1795, both of which were designed to help the United States avoid any form of conflict with European powers.

Although the presidents who succeeded Washington attempted to preserve his isolationist ideals, growing tensions with Great Britain eventually led the United States into its first War, 36 years after its inception. The War of 1812 was an extremely poor military showing from both

⁴⁶ Effects of Income Tax Changes on Economic Growth, William Gale & Andrew Samwick, Brookings.edu, September 2014

sides, and it ultimately ended as a stalemate, which allowed both sides to attain what they wanted from the war. Viewed as a great success in the eyes of the American people, the War of 1812 spurred an era of Nationalism that saw American foreign policy grow relatively tame, with the Mexican-American War being one of the only bold statements in foreign policy during the majority of the 19th century.

During the breakout of World War I in 1914, America originally desired to remain neutral. Woodrow Wilson, the president at the time, denounced the atrocities committed by both sides and worked to broker a peace. Eventually however, the German attack of RMS Lusitania, resulting in the death of 128 American civilians, led the US to enter the War in support of the Allies. The German forces were finally overwhelmed, and surrendered in 1918. After World War I, the United States entered a brief period of isolationism. They ended nearly all intervention in Latin America, and were content to let European affairs remain in the hands of European leaders. This period of isolationism ended with the beginning of World War II. After the Japanese attack on Pearl Harbor, the United States officially joined World War II as a full fledged member of the Allied Forces. The Allied Forces achieved victory in 1945, and the US isolationist policies that had graced the inter-war period were ended. The majority of United States foreign policy for the remainder of the 20th century was dedicated towards containing the spread of communism, most of which was done through the Cold War. Numerous proxy wars by the United Nations against China and the Soviet Union were fought for this purpose, such as the Korean War from 1950-1953 and the Vietnam War from 1965-1975. Eventually, the Soviet Union was dissolved in 1991, ending the United State's 40 year struggle against communism.

The beginning of the 21st century saw the USA adopt yet another shift in their foreign agenda. The tragic bombing of the Twin Towers in 2001 led to the beginning of the "War on Terrorism", resulting in US military involvement in various Middle Eastern nations known for their support of militia groups.

With this many shifts in foreign policy and military goals, economists have varying stances on the effect this important sector of government has on the economic rate of growth. Some state that entering in unnecessary conflicts with other superpowers only causes economic downturn, while others believe that an aggressive foreign policy aids in economic growth via new markets and overall expansion.⁴⁷ The data however, appears to convey a message dissimilar

⁴⁷ The Effect of War on Economic Growth, Clifford Theis & Christopher Baum, Cato Institute, 2020

to both of these viewpoints. Figure 3 contains a chart of the longest wars in American history, and compares it to a graph of real GDP over time. If we observe the growth of real GDP over a period of war, it is apparent that they have nearly no correlation. For example, based on the chart, the Iraq War was one of the longer wars in United States history, ranging from 2003-2012, but if we observe the growth of real GDP over that 9 year period, there doesn't appear to be any major fluctuations to reflect the war.

On the other end of the spectrum, the Spanish American War was one of the shorter wars in American history, spanning from 1898-1899, and yet again there still does not appear to be much change in the growth of real GDP during that time period. Therefore, while there are exceptions to this case such as the Vietnam War (Government debt caused by the war resulted in a minor recession), and World War 2 (Military necessities helped bolster the economy after Great Depression), for the most part, foreign policy does not appear to have a major or long lasting effect on the Economic Rate of Growth.

Overall Government Expenditure

A large portion of a government's authority rests on its expenditure. Government expenditure can be broken down into direct purchases of goods and services, and government transfers.

Purchases of Goods and Services

Government expenditure in the form of purchases of goods and services can be defined as directly buying the supplies and manpower required to undertake whatever task is deemed beneficial to society.

Two of the biggest sectors that rely on this form of expenditure are the Military and Infrastructure development. Naturally, the National Defense budget rises during times of war and decreases during times of peace. As stated in the previous section, economists have differing opinions on the effects of war on the economic rate of growth, and their views on military expenditure are equally debated. Some economists believe that money spent on the military would be more beneficial to the economy if spent in other areas, while others argue that maintaining a strong military is of the utmost importance, as dissuading potential threats to

national security, and keeping the peace, will contribute to the betterment of the economic rate of growth.⁴⁸

Although logically sound, these views do not seem to be in line with the data. In Figure 4, a graph of the National Defense Budget of the USA over time, is compared to the graph of Real GDP over time. We can see many massive spikes in the Defense Budget during times of war, and many times of low military spending in times of peace, but none of these spikes is represented in the graph of Real GDP, which appears to grow steadily, independent of National Defense spending.

While the benefits and drawbacks of military spending are constantly debated, most economists view expenditure on infrastructure in a positive light. Improved infrastructure leads to an increased quality of life, which is believed to consequently better the economic rate of growth. However, similar to military spending, the data seems to show that changes in the budget of infrastructure development has little effect on economic growth. Figure 7 displays a graph of government expenditure on infrastructure over time, compared to Real GDP over time. Although much smaller than the spikes on the graph of the National Defense Budget, expenditure on infrastructure still has significant ups and downs over the 80 year time span represented by the graph. Conversely, the Real GDP seems to maintain its steady growth rate and appear to be unaffected by changes in infrastructure expenditure.

Government Transfers

Government expenditure in the forms of transfers can be defined as government payment that indirectly aids in the redistribution of wealth and resources. The two biggest examples of government transfers are healthcare and social security.

Medical knowledge, technology, and resources were scarce for much of America's history. For much of the early 19th century, hospitals were a rarity and those that did exist, did not have the knowledge or skill required to help most of their patients. The Civil War brought about a big change in the medical standards of the USA. The Union army built many army hospitals all over the country, and new ideas and techniques were developed with the research conducted during the war. After the war, senior surgeon John Shaw Billings established the

⁴⁸ How Does Defense Spending Affect Economic Growth, Bryan Rooney & Grant Johnson, Rand Corporation, 2021

Library of the Surgeon General, which has become the hub for American medical information. While the quality of healthcare had been substantially improved, the payment system was still a direct fee for service, and there was virtually no health insurance offered at the time.

As the industrialization of America continued into the early 20th century, companies began to offer sickness protection to workers who worked in dangerous positions. This system eventually turned into the creation of employer sponsored health insurance, as we know it today. Although employer sponsored healthcare was a considerable improvement, it still did not provide any aid to those who could not work, such as retirees and disabled people. Various administrations attempted to combat this issue by creating nationalized healthcare, but the American Medical Association fiercely combated each plan, labeling nationalized medicine as “towing the Soviet Line”. Lyndon B. Johnson, the 36th president of the USA, finally succeeded in attaining some form of aid for the elderly and disabled, with his creation of Medicare and Medicaid.⁴⁹

Most economists feel that improved healthcare is helpful to the growth of an economy, as better healthcare results in higher rates of productivity, thereby benefiting the economic state of the country. Data, such as the graphs shown in Figure 6, appear to support this claim, as they show that Real GDP and Healthcare expenditure seems to be growing at a similar, positive rate. However, if we consider the fact that government sponsored healthcare was next to nothing prior to 1965, it becomes apparent that although the NHE and Real GDP have grown at a seemingly correlational rate since the 1960s, federally sponsored healthcare does not seem to have a direct impact on the economic rate of growth.

Antitrust

Another major portion of government regulation is Antitrust policy. In simple terms, antitrust laws are passed with the intention of promoting fair business practices and maintaining competition in the market.

The first major example of antitrust policy in the United States is the Sherman Antitrust Act of 1890. Passed in response to many railroad companies being consolidated into giant systems, the Sherman Antitrust act outlawed any attempts to restrict trade and form monopolies. American officials placed high priority on enforcing antitrust laws during the progressive era,

⁴⁹ The History of Medicine and Organized Healthcare in America, Jeff Griffin, Griffin Benefits, March 2020

with Presidents Theodore Roosevelt and William Howard Taft suing a combined 120 companies under the Sherman Act during their respective presidencies.

Although the Sherman Antitrust Act proved to be an essential step in American antitrust policy, by the early 20th century, many perceived it to be far too basic. Under the act, businesses were reportedly not entirely sure of the extent to which they could expand before being considered a monopoly, and government officials were like mindedly confused of their capacity to break up big business. This led congress to pass the Clayton Act in 1914, which specified the actions that businesses were prohibited to take, helping tie up the loose ends left by the Sherman Act.

After the Progressive era however, strong Antitrust policy temporarily faded from government priority. Companies such as Ford were celebrated for doing the same things that entities such as the Standard Oil Company were crucified for in years prior. The early years of the New Deal only added to this shift away from antitrust policy, as administrations leaned towards industry-government cooperation.⁵⁰

The eventual reemergence of hostility towards big business in America came during the 1940s, when antitrust began to be viewed as a method to combat fascism and preserve economic/political freedom. Administrations once again heavily relied on the Clayton and Sherman Acts in order to combat rising monopolies, and the American attitude towards big business has remained relatively consistent since.

Economists generally speak of strong antitrust policy as a positive for economic growth. It prevents the risk of prices skyrocketing due to monopolization and can foster innovation in various sectors by promoting competition.⁵¹

However, this idea does not seem to be supported by the data. Antitrust policy was next to nothing prior to the Sherman Act of 1890, and therefore if breaking up big business truly aided in bolstering economic growth, then there should be a visible increase in the economic rate of growth post 1890. As displayed by the graph of Real GDP over time in Figure 8, instead of exhibiting a change in the rate of growth, Real GDP seems to increase at roughly the same rate throughout the influx of antitrust policy during the late 19th/early 20th century.

⁵⁰ The Rise, Fall, and Rebirth of the U.S Antitrust Movement, Maurice Stucke & Ariel Ezrachi, Harvard Business Review, December 2017

⁵¹ The Dynamic Effects of Antitrust Policy on Growth and Welfare, Laurent Cavenaile & Murat Celik, University of Toronto Faculty, February 2021

Therefore, despite the large emphasis that the American government has placed on antitrust policy throughout the past century, the data seems to convey that the economic rate of growth remains mostly unaffected by variations in hostility towards big business.

Comparisons to other countries

Although the prior sections do thoroughly examine the effect, or lack thereof, of government policy on the economic growth for the United States, it is essential to also look for this trend in other nations. Examining all the aspects of government policy for multiple other countries would be a painful process, but we can use overall Government expenditure to represent the “size” of government in that nation, and once again utilize the Real GDP to represent economic growth.

Consequently, Figure 9 contains the graph of G7 Gov. Expenditure as a % of GDP over time, and compared it to a graph of Real GDP over time for multiple of the countries in the G7. If we look at the data for Great Britain, it appears that Government spending remains on a mostly consistent path of growth until the ~1980s, where it seems to plateau. Although Britain’s Real GDP does somewhat correlate with the growth of Gov. Expenditure for a long period of time, the recent ~25 year plateau in Government spending is not reflected in the Real GDP, which continues its consistent growth during that period. Most of the other countries in the data set also seem to follow this trend of shared growth between Real GDP and government spending until the late 20th century, where expenditure appears to stagnate while Real GDP continues growing.

This brings up the possibility of Bidirectional Ambiguity between the data, as the correlational growth between the countries’ Real GDP and Government expenditure does not remain consistent over the entire time period examined, meaning that their shared growth may have been coincidental, revealing that similar to the USA, other nations do not appear to exhibit a direct correlation between Government policy/expenditure and economic growth.

Conclusion

To be clear, the analysis here can only examine the impact of government policies over the range of intervention that has occurred so far. Thus, for example, the conclusion that

government spending has not obviously helped or hurt the economy so far does not tell us whether a substantially higher level of spending, or a much greater degree of regulation, might start to have negative impacts (e.g., as in highly controlled economies like Cuba, North Korea, or the former Soviet Union).

But the results here do suggest that the large emphasis put on government regulation in relation to economic growth, may be somewhat misplaced.

Figure 1

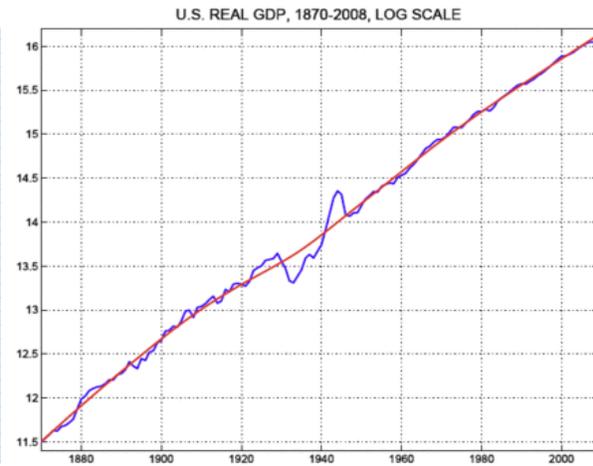
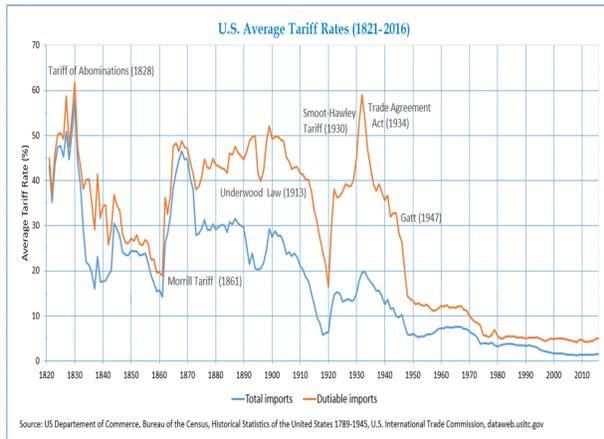


Figure 2

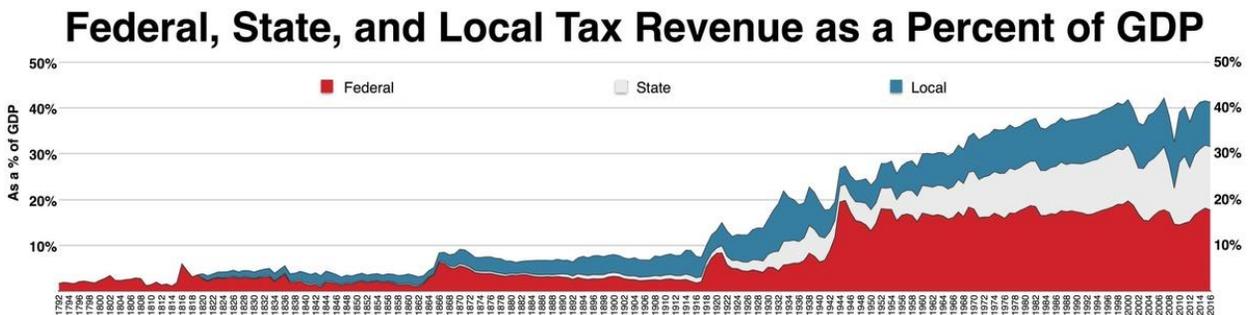


Figure 3

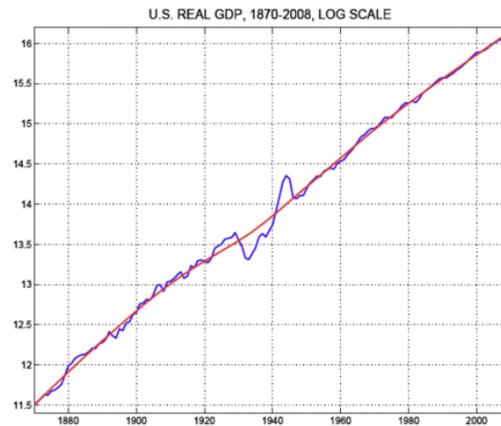


Figure 4 (Graph of Defense Spending/time vs Graph of Real GDP/time)

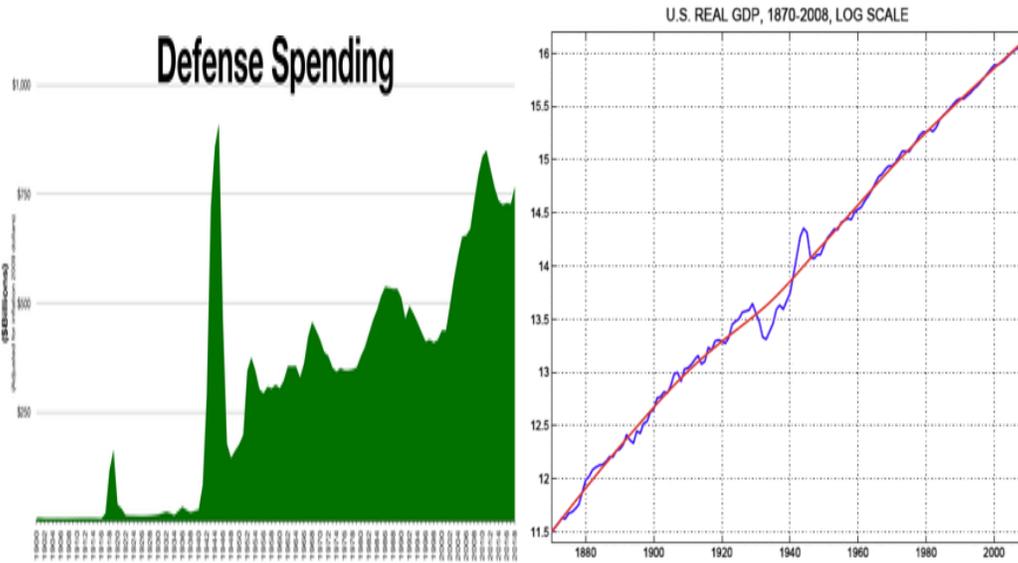
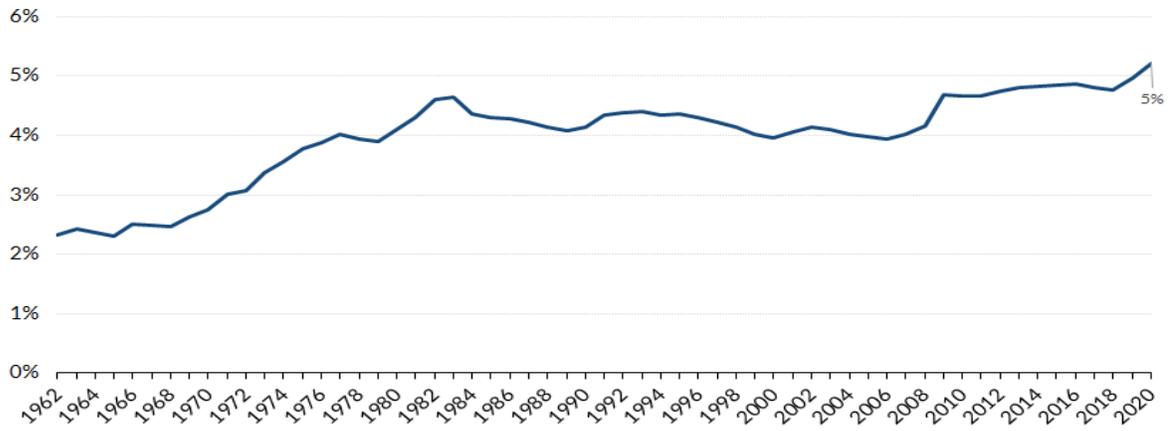


Figure 5

Social Security Expenditures
 Percentage of GDP, fiscal years 1962 to 2020



Source: Office of Management and Budget, Historical Tables, Table 8.1; <http://www.whitehouse.gov/omb/budget/Historicals/> (last accessed June 7, 2021).

Figure 6 (Graph of NHE compared to Graph of Real GDP)

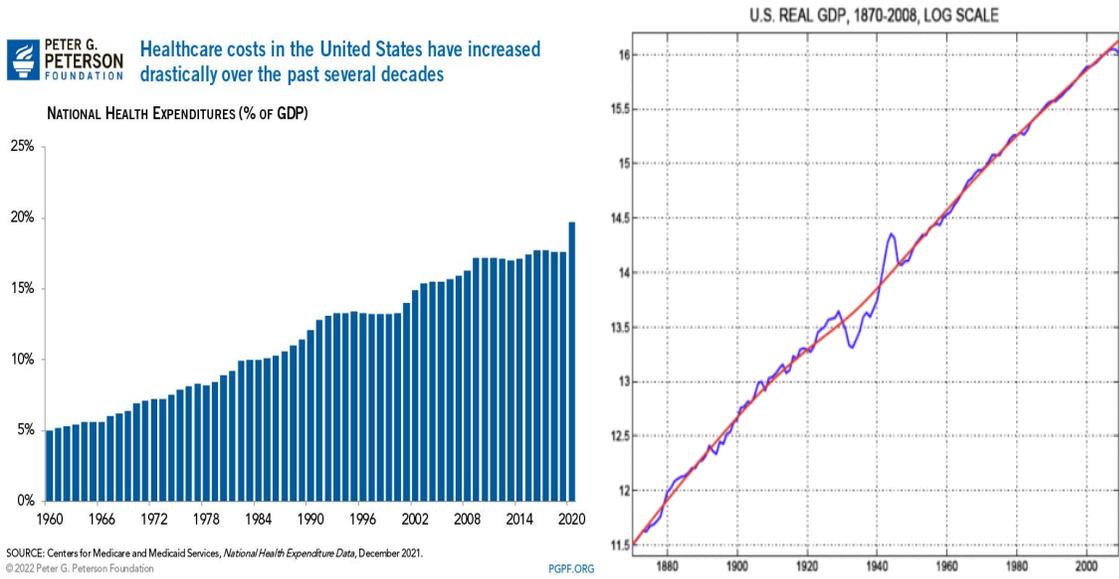


Figure 7 (Infrastructure spending/time compared to Real GDP/time)



Figure 8 (U.S.A Real GDP/time)

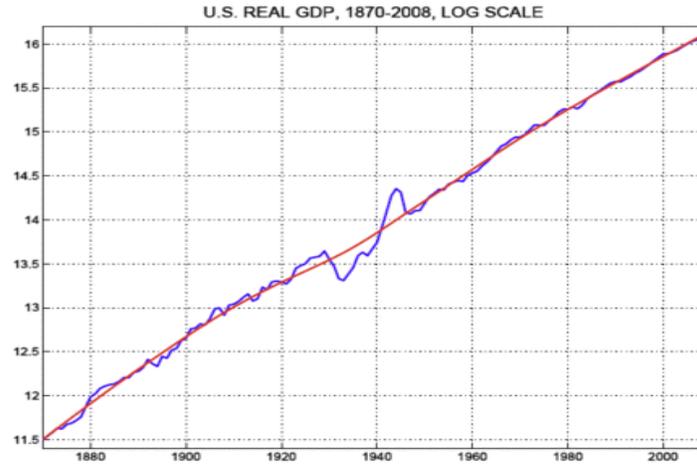
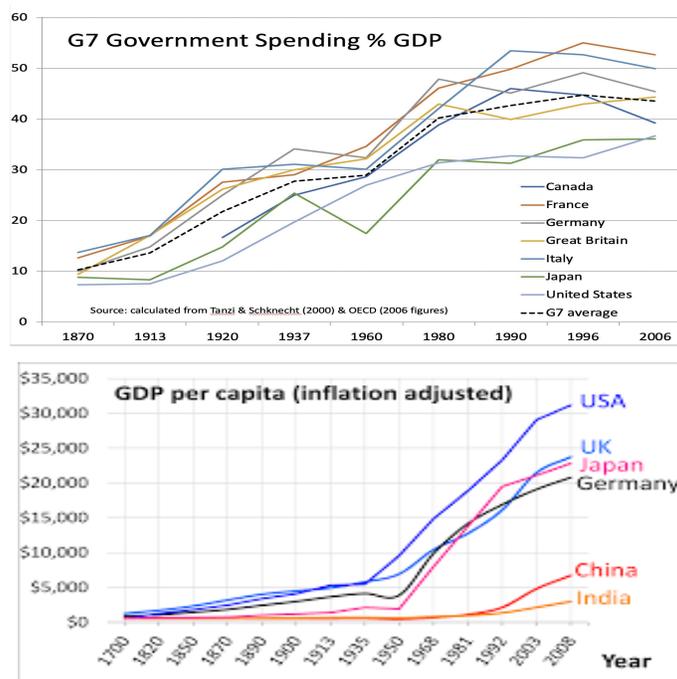


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The Limitations and Solutions of Stem Cell Use in Cancer Treatments by Surabhi Bhaskar

Abstract

Stem cell therapy is an important treatment in the context of cancer. The use of embryonic stem cells in this field of study are controversial due to their origin from fetal cells and allogeneic stem cells have been a proposed alternative. While a preferred treatment, donor stem cells are accompanied by a host of issues, like graft-versus-host disease and rejection of the treatment. Due to recent advancements in the field, solutions to these problems are closer than ever. Radiation and chemotherapy are common therapeutic methods used to destroy cancerous cells and stem cells can be used to replenish the body with healthy cells. Stem cells can also be used as vehicles to carry chemotherapies to the tumor site. Chimeric antigen receptors (CARs) can be used to direct the stem cell transplant to the intended location and integrins can be used to contain them to that area. In order to prevent rejection of the graft by the host's immune system, certain proteins can be added and removed from the cell's surface through ex-vivo modification. Clinical trials have yielded promising results for these advancements in the treatment of cancers.

Discussion

Stem cells are the functional units that other cells of the body, such as blood and liver cells originate from. Through differentiation, stem cells become specialized adult cells or self-renew to maintain the pool of stem cells throughout the body. When a cell differentiates into an adult cell, it loses its potential to develop into any other type of cell that the body may require at a given moment. With this ability to produce various somatic cells, the development of a technique that takes advantage of stem cells to treat diseases and conditions has been a point of research for the past decades.

Regenerative medicine works to reproduce body tissue and organs in order to get them to function as they typically would. Researchers in this field of study have used stem cells to generate new, healthy cells to replace damaged adult cells. Burns, for example, are candidates for this treatment as skin cells have been destroyed by heat and stem cells can replenish the damaged tissue by supplying the body with new skin cells¹. Due to donor organs being limited in supply, the development of stem cell therapy could prove to be a useful, more cost-effective alternative to organ transplants.

Sources of stem cells consist of embryos, adult tissue, amniotic fluid, and umbilical cord blood². There are different types of stem cells, all with varying degrees of differentiation potential. Embryonic stem cells are extracted from blastocysts and are considered pluripotent, meaning that they can differentiate into a host of somatic cells³. This is opposed to cells taken from adult tissue where, although there are stem cells present in bone marrow or fat, adult stem cells are limited in number and in their ability to differentiate into cells other than those of the region they were taken from.

Totipotent cells, like zygotes formed from the fertilization of an egg by sperm, have the highest differentiation potential, meaning that cells can form embryonic and extraembryonic structures. Totipotency enables these cells to develop into a germ layer or placenta, yet another plentiful source of pluripotent cells⁴.

Despite having a wider potential for clinical use, embryonic stem cells are restricted by the donor cell being incompatible with the patient's immune system and the controversy surrounding their origin. The former can be addressed through therapeutic cloning where the nucleus of the recipient's somatic cell is transferred into the egg cell. This allows pluripotent cells taken from embryos to be accepted by the host's body instead of being rejected and attacked by the immune system⁵. However, this method is very expensive and relies heavily on available technologies. Additionally, it is not highly efficient as its yield is low. Moreover, the use of embryonic stem cells is controversial because they originate from human blastocysts only five to seven days old. In 2009, the National Institutes of Health established guidelines for human stem cell research to address the matter. Embryos created through in vitro fertilization are available for use when the embryo is not required by the egg or sperm donor and with informed consent from the individuals⁶. Still, some researchers have opted for a different approach to stem cell therapy that doesn't involve the use of embryonic cells.

More recently, there has been development on a method to revert specialized cells back into their pluripotent state. By taking a differentiated somatic cell—commonly a skin cell—and using specific transcription factors like the Oct4, Klf4, Sox2, and c-Myc proteins, researchers can control and change the behavior of the cell⁷. Induced pluripotent stem cells, due to their high cost, are more often used for drug testing and disease modeling as opposed to clinical treatment.

Tumor Tropism

As described above, stem cells are often acquired from a donor since the patient's damaged tissue cannot provide sufficient cells for the treatment. An example of this includes leukemia patients, whose bone marrow has been obstructed through chemotherapy or radiation directed at tumors of blood-forming tissues. Allogeneic transplants use donor cells to replenish the cells displaced by the cancer and destroyed by therapies to prevent metastasis.

The ability to grow and multiply at a rapid rate is part of what makes cancers such a destructive force. Chemotherapy targets this characteristic by administering drugs intravenously, orally, or topically to kill rapidly-dividing cells in the body by inhibiting their ability to divide and replicate their DNA. Stem cells can be used in conjunction with chemotherapy in order to deliver the treatment to the tumor site. Tumor tropism occurs when the tumor site induces chemoattraction of surrounding cells, often including stem cells⁸. While this is a detriment to the restoration process, it can be taken advantage of by using stem cells to carry a therapeutic drug, such as chemotherapy, to successfully deliver the treatment to the tumor site.

Mediating Graft-Versus-Host Disease

Complications of the immune system as a result of transplanted stem cells recognizing the host's body as foreign can develop following an allogeneic transplantation. This unintended off-target effect could be mediated by better controlling the localization of transplanted cells. This can be done with chimeric antigen receptors (CARs), which are proteins that can identify specific antigens. For instance, CD19 is an antigen expressed on all B-lymphocytes. T-cells, if genetically modified to express anti-CD19 CARs (CAR19), will possess properties designed to combat any identified CD19+ target cells⁹. CD19 CARs are an example of modifying transplanted T-cells to target the CD19-expressing tumor and minimize off-target effects. This same concept could be applied with stem cell transplants to minimize off-target effects. This therapy has proven revolutionary in treating leukemias; however, it is limited by how costly the use of T-cells is and each transplant requires T-cells from the individual patient. This technology can be enhanced by instead utilizing stem cell-derived T-cells, which have been shown to minimize rejection of the transplant.

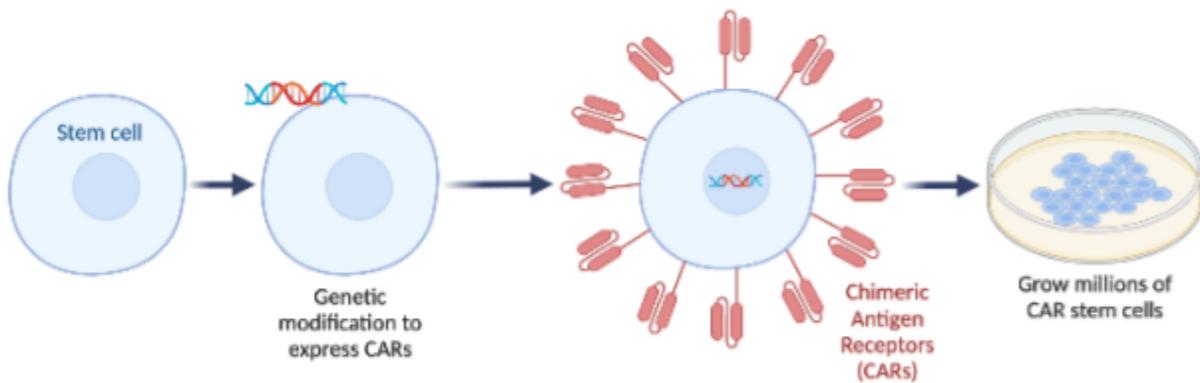


Fig. 1 | Adding CARs to stem cells. A stem cell is obtained and modified to express a gene that codes for CAR proteins. The modified CAR stem cell is then expanded to provide sufficient numbers for transplantation in order for the body to take up the graft. This will allow the cell to better target the tumor site as the CAR that is being expressed can identify an antigen specific to the tumor site. Created with BioRender.com

Another obstacle to overcome is retaining the stem cell treatment at the tumor site to minimize off-target damage. Integrins are receptors that regulate cell proliferation, survival, and motility—all vital to metastasis¹⁰. They can bind to extracellular matrix components (ECM) like ligands—ions or molecules bound to a metal atom—and cause outside-in signaling through which ECM molecules are able to bind to the receptor and take effect. Integrins can contribute to the progression of cancers and thus, being able to target integrins would minimize host damage. The most frequently studied integrins in cancer are $\alpha v\beta 3$, $\alpha v\beta 5$, $\alpha 5\beta 1$, $\alpha 6\beta 4$, $\alpha 4\beta 1$ and $\alpha v\beta 6$ because the tumor cell expression of these receptors are linked to disease progression in several types of tumors¹¹. Since integrins correlate with the survival of the cell, integrins bound to ligands relay survival signals whereas unligated integrins promote apoptosis or programmed cell death. Tumors are characterized by their inability to perform apoptosis, leading to its uncontrollable growth. Therefore, by initiating integrin-mediated death, integrins can counteract their function of promoting cell growth and combat the tumor that it would otherwise allow to progress if ligated.

More pertinent to stem cell therapy, recent studies have shown overexpression of select integrins can increase retainment of stem cells in the desired location. In cardiac regeneration, a 25% improvement of cardiac performance post transplantation was reported when this method was used¹². Through this method, modified stem cells that use integrins to keep them to specified locations can prevent off-target effects and enable the treatment to combat the tumor with greater

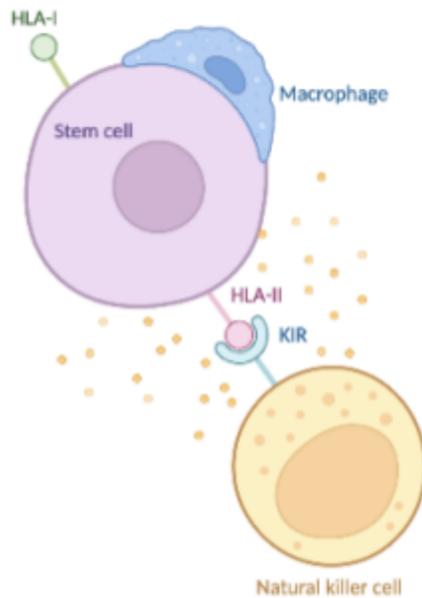
precision. Since $\alpha\nu\beta3$, $\alpha\nu\beta5$, $\alpha5\beta1$, $\alpha6\beta4$, $\alpha4\beta1$ and $\alpha\nu\beta6$ are important for tumor progression, overexpressing these integrins can similarly boost retainment of stem cells to the tumor site.

Mediating Rejection of Stem Cells as a Cancer Treatment

When taking up an allogeneic treatment, there is a risk of the host's immune system recognizing the graft as a substance foreign to the body and attacking it. This is as opposed to syngeneic transplants in which identical genetic information is used. However, through ex-vivo modification of the allogeneic graft, the host's immune system can be surpassed. Gene editing allows for the creation of stem cell therapies that are universally immunocompatible and thereby will not face rejection by the host⁸.

Human leukocyte antigens (HLA) are markers present on the surface of most cells of the body that allow the immune system to detect whether a cell is foreign or native to the host. By removing HLA proteins from the cells, the immune system would not detect the presence of foreign antigens. Then, the addition of PD-L1 and CD47 keeps macrophages from consuming cells that are not malignant, like the graft which may be mistaken as harmful¹³. HLA-E is added to make the cell appear normal despite its lack of a classified marker¹⁴. Killer Ig-like receptors (KIR) expressed on natural killer cells won't detect the absence of HLA proteins and will defer lysis.

Host immune system's reaction to allogeneic graft pre-modification.



Host immune system's reaction to allogeneic graft post-modification.

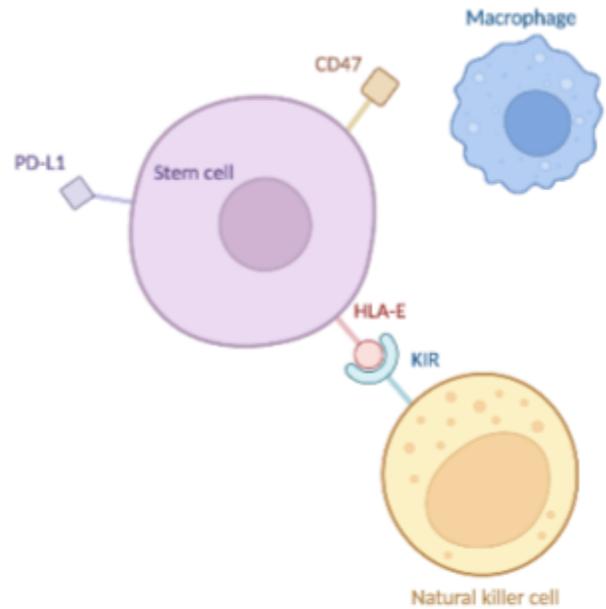


Fig. 2 | Rejection of the allogeneic graft. The immune system reaction when in contact with allogeneic stem cells without (left) and with (right) any external modification. The stem cell pre-modification will be recognized as foreign by NK cells when the HLA proteins on the stem cell bind to the KIR receptors on the NK cells. Then, NK cells will release cytotoxic granules that trigger lysis of the cell. By contrast, a modified stem cell will have the HLA-E protein which is a universal marker unlike HLA-I or HLA-II and therefore will not be identified as foreign to the body by the KIR receptor. This will not trigger the release of granules from the NK cell and will prevent cell death. Created with BioRender.com

Conclusion

Stem cell therapy is an evolving field of study. Its applications extend across a vast array of medical specialties, but in the context of cancer, there is a great deal of promise for effective treatment methods. The cost of replacing a failing organ entirely with a donor organ is expensive and time-consuming as the recipient is placed onto a waitlist amid other patients in varying circumstances. Stem cells, by comparison, have greater potential for convenient access. Due to controversy over embryonic stem cells, researchers are opting for the use of allogeneic hematopoietic transplants; however, they are not without their limitations. In order to curate the optimal course of treatment, it is imperative that any and all barriers are addressed. Such barriers in a successful treatment include rejection of the graft, off-target effects, and further metastasis of

the tumor. These barriers can be addressed through gene editing such as CARs and integrins which are ex-vivo modifications to the stem cell.

In addition to obstacles present in the treatment itself, cost and accessibility are practical concerns that require attention. Despite the success T-cells harnessing CARs have in targeting specified B-lymphocyte antigens present on the surface of affected cells, it is an expensive source to tap into. Stem cells, on the other hand, are a much more cost-effective alternative as they can be reproduced in stem cells lines and have greater potential to be a more widespread treatment. Furthermore, as stem cells can be modified ex-vivo to be suitable for virtually any recipient, it is much more accessible than T-cell based therapies in which the cells need to be provided by the individual to prevent rejection of the graft.

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The Need for Repair: British-India and the Case for Colonial Reparations by Vidhi Bhartiya

Abstract

This paper establishes a definition and precedent for reparations, specifically in regards to British-Indian colonialism. It categorises reparations into those for war and slavery, and differentiates colonial reparations in the Indian context from the former two forms prevalent in contemporary discourse. I argue that colonial reparations are necessary due to the negative socio-economic impact of colonialism on India and its people. In the latter half of the paper, I invoke, and debunk, arguments espoused by colonial apologists, many of whom have argued that industrialization and modernization were positive products of the colonial endeavour. This, I argue, was far from the truth, as India was actually systematically de-industrialised to propel Britain's industrialisation and conquest. Even the infamous colonial railroad was not built to serve the Indian population but to assist the British Raj in the export of Indian raw material and the import of British goods. All modernization, then, should be considered self-serving as opposed to benevolent. Additionally, I will explore the lasting effects of unequal economic development on modern trading amongst nations, and the established power disparity stemming directly from colonial rule. Colonialism, I argue, still retains a significant impact on the postcolonial world that we inhabit today. This paper aims to highlight the enduring legacy of colonialism in the present, and build a case for reparations being provided to India, specifically, and , more broadly, former colonies in the Global South.

Introduction

Although most colonies in the Global South were granted independence in the mid-20th century, the impacts of colonialism still remain. The socio- economic and cultural imbalance left behind in these countries even after colonists left their shores has resulted in a deeply unequal world. Colonial powers continue to dominate the global playing field through power they built on the backs of downtrodden colonies. Meanwhile, "developing" countries struggle to undo the damage their former rulers left behind. Due to the skewed structure of the global economy in

favour of the Global North, the Global South approximately loses 24 dollars in net outflow for every dollar of aid they are provided.⁵²

Reparations can be understood broadly as compensation for abuse or injury suffered by the victims. This paper argues for former colonies to be awarded reparations for the socio-economic damage suffered under colonial subjugation, and explores colonialism through the case of British-India. India was largely independent from the Atlantic Slave Trade, and therefore is largely uninvolved in the current slavery-specific discourse around reparations. In India, the colonial policies revolved largely around resource exploitation and industrialism. Therefore, the case for colonial reparations for India will be made distinct from reparations for war, or the effects of the Atlantic Slave Trade. This paper will explore the direct and indirect effects of colonial rule, which have led to a global power disparity and Western hegemony – further proving the necessity of reparations beyond a solely economic or sociological lens.

Defining Reparations

Traditionally, reparations were considered punitive mechanisms to extract compensation for damages suffered by the victorious party, to be paid by the defeated party. An early example of such reparations was the imposition of indemnities on Carthage by Rome during the Punic wars, where Rome required Carthage to compensate Rome for the losses it suffered during war. Today, we can class these types of reparations as war reparations.

Another type of reparations rose to popularity in the twentieth century. A prevalent example is the Canadian government's official apology to the indigenous community (Cowessess community and Treaty Four communities) for the Canadian residential schools. The government also allocated funding for indigenous community members to find their loved ones who died in such institutions. As transitional justice gained traction, "Persons who individually or collectively suffered harm, including physical or mental injury, emotional suffering, economic loss, or substantial impairment of their fundamental rights, through acts or omissions that constitute gross violations of international human rights law" were entitled to receive reparations from the state.⁵³

⁵² Jain, Sparsh. "Colonialism, Development, and Reparations: The British in India." *Crossfire KM*, Crossfire KM, 13 Aug. 2020, <https://www.crossfirekm.org/articles/colonialism-development-and-reparations-the-british-in-india>.

⁵³ "Reparations in Theory and Practice." *Reparations in Theory and Practice* | *International Center for Transitional Justice*, <https://www.ictj.org/publication/reparations-theory-and-practice>.

On 16th December 2005, the United Nations passed a resolution for Reparations for Victims of International Human Rights Violations. According to the UN Basic Principles and Guidelines, reparations can be claimed by victims of human rights violations, encompassing the following five categories⁵⁴:

1. Restitution: the aim to help restore a victim back to their original situation before the violation of human rights occurred. This can involve the restoration of liberty, return of residence, restoration of employment and more.
2. Satisfaction: encompasses methods like truth-seeking, commemoration, judicial and administrative sanctions and the recovery and reburial of remains.
3. Damages compensation: the provision of compensation for any economically assessable damage, like physical or mental harm, material and moral damages and loss of earnings.
4. Rehabilitation: the provision of medical, psychological, social services and legal assistance.
5. Guarantees of non-repetition: reforms ensuring the prevention of future abuses.

Article 16 of the “Charter of Economic Rights and Duties of States” outlines that all states which have practised colonialism or aggressive foreign policy are responsible for the restitution and full compensation for the exploitation, depletion, and damage of natural resources in postcolonial states. However, this has not been the case for postcolonial India.

The Necessity of Reparations

Reparations for colonial rule, or colonial reparations, can be considered as damage compensation to restore colonies to their pre-colonial socio-economic status. Reparations are required to provide victims with justice, along with compensating subsequent generations for their suffering. Postcolonial states, after independence, were left floundering. Their national accounts were in deficit due to colonial trade policies, and they had negligible industrial infrastructure compared to the Western powers with whom they traded. The agricultural sector in

⁵⁴ “Basic Principles and Guidelines on the Right to a Remedy and Reparation for Victims of Gross Violations of International Human Rights Law and Serious Violations of International Humanitarian Law.” *OHCHR*, <https://www.ohchr.org/en/instruments-mechanisms/instruments/basic-principles-and-guidelines-right-remedy-and-reparation>.

such economies was largely driving their GDP, and they struggled with building independent economies without established manufacturing or service sectors. In many cases, as in India's, the deindustrialisation was a deliberate policy tool employed by the British Raj to turn the colony into a captive market for profit. Discriminatory taxes and duties were levied to increase demand for otherwise inexpensive English goods and to reduce the competitive value of Indian goods internationally. Indian raw material like cotton was bought at exceedingly cheap prices by the colonists and the finished goods were sold to Indians at higher prices, as was the case in the clothing trade (example: clothing). Estimates show that pre-colonisation, India's GDP was 27% of the global output, and, post-colonisation, declined to a mere 3%.

Economic Underdevelopment & Racial Formation

The absence of discourse around colonial responsibility is accompanied by a countervailing discourse touting the Global North to be inherently superior to the Global South. Developing countries are thought to have civilizational defects that have resulted in their inability to catch up to the West, which in turn has prospered solely due to ingenuity and strength. Race and racism were created as tools to justify colonial projects globally - a legacy that remains with us today.

Policymakers have seen fit to make discriminatory and racist remarks against former colonies. The former Prime Minister of the United Kingdom, Boris Johnson, in 2002 remarked about Africa, "no doubt the AK47s will fall silent, and the Pangas will stop their hacking of human flesh, and the tribal warriors will all break out in watermelon smiles." He also remembered colonial rule in Africa favourably, saying that "the continent may be a blot, but it is not a blot upon our conscience...The problem is not that we were once in charge, but that we are not in charge any more."⁵⁵ His words reflect popular sentiment- due to lack of contextual education, European citizens often look back on colonial rule favourably, thinking that they were benevolent rulers who served to benefit their colonies, and many want to return to when "the sun never set on the British empire". Such attitudes are accompanied by a "white-saviour complex" which sees developing countries as unable to guide themselves as successfully as the Europeans could.

⁵⁵ Jain, Sparsh. "Colonialism, Development, and Reparations: The British in India." *Crossfire KM*, Crossfire KM, 13 Aug. 2020, <https://www.crossfirekm.org/articles/colonialism-development-and-reparations-the-british-in-india>.

This narrative ignores the economic advantages gained through the exploitation of colonies provided in developing the Global North. Industrialisation and globalisation in developed countries occurred not only parallel to, but because of the systematic de-industrialisation and isolation of colonies. It has created a fundamentally unequal hierarchy, where socio-economic and military power is skewed in favour of former colonial powers. Power in most international bodies - The United Nations, the World Trade Organisation, The International Monetary Fund and the World Bank - is concentrated with colonial powers. While the Global South contains 80% of the global population, they command less than 50% of the vote at these forums.⁵⁶

The developed world has owed their 'development' to having a head start in a race colonies joined less than a century ago. Colonialism enabled the developed world to participate in arms races and establish a technological monopoly while newly independent countries still struggled to establish democratic administrative systems and rebuild dismantled economic systems. International bodies then imposed treaties and conventions on developing countries, effectively curbing their ability to ever collate the same power the Global North already had. In 1998, India was forced to carry out nuclear tests in secrecy due to arbitrary international regulation banning the establishment of new nuclear countries - a move which cemented nuclear power in the hands of the elite few.

The impact of the Atlantic Slave trade can be measured not only in terms of the economic harm and exploitation of the land, but also the propaganda fed to the masses which has manifested in the racist attitudes prevalent today. The Atlantic Slave Trade and the denouncing of Africans as inferior - even biologically and culturally less than human - were the catalyst for the subsequent centuries of oppression and suffering by African descendants worldwide. In order to justify colonial conquest, the British painted a picture of Africa as a barbaric land that the noble colonists were 'civilising'. Colonial brutalities were justified as the 'white man's burden' and a benevolent project of racial uplift. The image of the continent as war-torn and inhabited by heathens was disseminated across the globe, and used to justify slavery. Edward Long, the author of 'History of Jamaica' - a text which disseminated racist ideas across the globe - asserted that

⁵⁶ Jain, Sparsh. "Colonialism, Development, and Reparations: The British in India." *Crossfire KM*, Crossfire KM, 13 Aug. 2020, <https://www.crossfirekm.org/articles/colonialism-development-and-reparations-the-british-in-india>.

the human trade being carried out on the Atlantic was beneficial to Africans, who were being ‘rescued’ from the barbaric lands which would otherwise wholly consume them.⁵⁷

The oft-invoked anti-reparations argument is built on the assumption that colonialism was a stock concept - it happened at a single moment in time and definitively ended with the independence of the colonies. However, decisions made by colonists continue to play a significant role in colonies even today. The 1947 partition of British-India into India and Pakistan, along with the partition of Israel and Palestine, birthed two of the most high-conflict regions in the world. The abstract partition of Africa into states exponentially multiplied existing ethnic and lingual stressors. Similarly, the 1916 European division of the Ottoman Empire sparked a century of conflict. Ignoring tribal and ethnic boundaries like in Africa, they drew artificial state boundaries, which led to multiethnic communities conflicting with one another.⁵⁸

International Precedent

The discussion for reparations being owed to post-colonial states is not novel. The victims of colonial rule have long since realised how deeply the exploitation of their land and human resources have affected their development and progress. The prosperity of the First World has come at a direct cost to the Third World. Reparations have started to be presented as a viable option in international forums such as the CARICOM’S Reparations Commission (CRC) which was established after the 2001 World Conference against Racism in Durban. As early as 1928, the Permanent Court of International Justice made a landmark judgement in the *Factory at Chorzów* case, holding that “reparation must, as far as possible, wipe out all consequences of the illegal act and re-establish the situation which would, in all probability have existed if that act had not been committed.”⁵⁹

Another aspect of reparations can be identified in a case concerning Dutch-Indonesian colonisation. The *Rawagede* case was presented in front of the Hague Court concerning men murdered by soldiers in the Indonesian Province of South Sulawesi during the “cleansing” performed by the Dutch soldiers in a bid to stall the independence movement. In this instance,

⁵⁷ “The Roots of European Racism Lie in the Slave Trade, Colonialism – and Edward Long | David Olusoga.” *The Guardian*, Guardian News and Media, 8 Sept. 2015, <https://www.theguardian.com/commentisfree/2015/sep/08/european-racism-africa-slavery>.

⁵⁸ Jain, Sparsh. “Colonialism, Development, and Reparations: The British in India.” *Crossfire KM*, Crossfire KM, 13 Aug. 2020, <https://www.crossfirekm.org/articles/colonialism-development-and-reparations-the-british-in-india>.

⁵⁹ *Factory at Chorzów* (Court of International Justice 1928).

the Hague Court ruled in favour of reparations being provided to the victims of the cleansings.⁶⁰ Similarly, in *Ndiku Mutua & Others v. The Foreign and Commonwealth Office*, a case was made against the Government of the United Kingdom for the atrocities committed by the British during the Mau Mau uprisings in Kenya in the 1950s, Justice McCombe ruled that there was a case to be made for reparations.

Historical precedent, therefore, illustrates that reparations are not an impossible idea. These are tangible instances wherein claimants were awarded compensation to repair damage caused by colonial authorities. These isolated incidents of colonial violence have qualified for reparations, but a more holistic view of centuries-long colonial rule has not yet been considered eligible for reparations. Through the lens of colonial India, I argue that colonies should receive reparations for sustained exploitation and its enduring impact. British-India is a part of a larger story of undevelopment, and the present need for repair.

Aftermath of Colonial Rule in India

Before 1757, India acted as the battleground where the Portuguese, French, and British competed for monopoly over trade. British rule in India was effectively established after the English victory at the Battle of Plassey. Almost immediately after this victory, the colonists set about expanding their sphere of control – starting at Calcutta and moving across India. The profits gained by the East India Company in their conquest largely financed their military campaigns across the subcontinent.⁶¹

Economic Harm

According to historian William Dalrymple, “The economic figures speak for themselves. In 1600, when the East India Company was founded, Britain was generating 1.8% of the world’s GDP, while India was producing 22.5%. By the peak of the Raj, those figures had more or less

⁶⁰ “Hague Court Orders Dutch State to Pay out over Colonial Massacres.” *The Guardian*, Guardian News and Media, 27 Mar. 2020, <https://www.theguardian.com/world/2020/mar/27/hague-court-orders-dutch-state-to-pay-out-over-colonial-massacres>.

⁶¹ “Amartya Sen: What British Rule Really Did for India.” *The Guardian*, Guardian News and Media, 29 June 2021, <https://www.theguardian.com/world/2021/jun/29/british-empire-india-amartya-sen>.

been reversed: India was reduced from the world's leading manufacturing nation to a symbol of famine and deprivation."⁶²

After the East India Company established a monopoly over Indian trade, they began to collect taxes in India. Unlike the native administration, the Company implemented fixed tax rates which ignored the impact of environmental fluctuations in the agricultural sector. Smaller farmers and landless labourers, for example, were disproportionately punished by the heavy tax levied even if crop yields turned out to be inconsistent with Company estimates due to factors like rain and soil fertility. The Company utilised this tax revenue to fund the purchase of Indian goods for use in Britain. They also re-exported Indian goods from Britain to the rest of the world, financing imports essential for their Industrial Revolution. India's underdevelopment was necessary for Britain's development - the two processes were linked.

While many argue that the sole blame for the economic exploitation of India lies with the Company, the Crown chose to pursue similar discriminatory and exploitative practices after taking over in 1858. Although the British Raj enabled Indians to export directly to other countries, profits still ended up in the Crown's hands.

To trade with India, one had to use 'council bills' issued specially by the Crown and purchased using gold and silver. Traders bought these bills and used them to purchase Indian goods, after which they had to cash in these bills with their local colonial office. They were paid in the money collected as tax revenue from them earlier by British tax collectors. In this manner, the British pocketed the gold and silver, which would originally go to the Indians, and prevented money from entering the country or the hands of its people. Although India ran a trade surplus till the early twentieth century, it still maintained a deficit in the national accounts.⁶³ Although the British allowed duty-free export of Indian raw material in order to fulfil Great Britain's industrial needs, they placed a heavy duty on the export of Indian handicraft goods. These relatively high--costing goods lost out to machine-made British goods, and the once-flourishing textile industry was dismantled. An 85% tax was levied on the export of Indian

⁶² "Amartya Sen: What British Rule Really Did for India." *The Guardian*, Guardian News and Media, 29 June 2021, <https://www.theguardian.com/world/2021/jun/29/british-empire-india-amartya-sen>.

⁶³ Hickel, Jason. "How Britain Stole \$45 Trillion from India." *Conflict | Al Jazeera*, Al Jazeera, 19 Dec. 2018, <https://www.aljazeera.com/opinions/2018/12/19/how-britain-stole-45-trillion-from-india/>.

chintz cloth and 44% on Indian muslin. By contrast, only a 5% tax was imposed on the import of British textiles.⁶⁴

During the British Raj, there was a decisive shift away from growing sustenance crops to grow cash crops. Earlier, most farmers engaged in subsistence farming, with the surplus sold in the market for profit. However, agricultural production from the 1860's onward depended on international demand for Indian raw material. This commercialisation limited growth in the agricultural sector; the lack of colonial investment and protection for farmers prevented industrialisation or any large-scale capital accumulation. Colonial policies only exacerbated the exploitation of small farmers and labourers who struggled under debt-traps and extractive taxes. The shift away from food crops also resulted in disastrous famine years. The decline in cotton demand resulted in famine and riot in the Deccan Belt in the 1870s, and the collapse of the Jute industry was followed by the Bengal Famine in 1943.⁶⁵ An estimated 3 million Bengali citizens perished and millions more were left impoverished. The diversion of Indian grain stores to support the war effort during World War 2 has also been credited with causing the Bengal Famine. In total, about 21.5 million people were affected by the 1873 famine, but little mortality was reported.

Railroad Colonialism

Although many pro-colonial arguments cite the construction of railroads as the most enduring and visible benefit to colonies, railroads - and their construction - were a tool of colonial subjugation meant to incur profit. Railroads reordered and reinforced the colonist-subject relationship, further entrenching the native population in imperialist market practices. The construction of Indian railroads allowed for the mass-shipping of British textiles and raw materials to all parts of the country, cementing India's role as a captive market. The spread of railways also gave rise to a new policy of subjugation through social difference. In 1860, a 'coolie class' was introduced on the train. This category of 'coolie worker' remained in India until, and following, the point of Independence – leaving an entire class of people without

⁶⁴ Venkatesa, Nikhil. "5 Ways Imperial Britain Crippled Indian Handlooms." *SGBG Atelier*, SGBG Atelier, 24 Nov. 2019, <https://www.sgbgatelier.com/world/2019/11/21/5-ways-imperial-britain-crippled-indian-handlooms>.

⁶⁵ 26 - *National Institute of Open Schooling*. https://www.nios.ac.in/media/documents/SrSec315NEW/315_History_Eng/315_History_Eng_Lesson26.pdf.

adequate social mobility. It was fashioned after a cattle wagon, with passengers squatting on the floor and only being let out at certain intervals. In India, the railways have stood to symbolise the horrors of partition-era India, when 1,250,000 people crossed arbitrarily demarcated borders to unfamiliar lands. The railways represent the unfinished nature of decolonisation, and the pain of division.⁶⁶

Lasting social Impact

Another enduring legacy of colonial rule manifests itself in the communal tension and religion-based violence prevalent in India today. The divide and rule policy employed by the British created friction between Hindus and Muslims, and eventually culminated in the Partition of India and Pakistan.

The colonists strategically incited the masses against the princely rulers, exacerbated caste division and created class divisions in attempts to divide and conquer India. After the first revolt of 1857, communal riots were artificially engineered by the British authorities. A British revenue collector would call a Hindu Pandit and instruct him to antagonise the Muslims. Similarly, a Muslim Maulvi would incite Hindu anger. This served to heighten tensions and prevent meaningful collaboration at the local level. Colonial policies like the English Education policy (which included Hindus but excluded Muslims) were designed to oust Muslims from the socio-political landscape since they were vehemently in opposition to British policies. Similarly, when the Indian National Congress rose to power, the British partnered with the Muslim opposition to counter the INC's influence. Lord Curzon's view of the Partition of Bengal in 1905 as an administrative measure fails to disguise the intentional division of Muslim-populated Bengal from Hindu-populated Bengal in order to suppress the Bengali intellectual circle, which led a powerful anti-imperial movement through the circulation of print-based media.⁶⁷ The antagonism fostered by the British continues to fester even today. The Hindu minority in Bangladesh and Pakistan, and the Muslim minority in India, continue to be oppressed as victims of discrimination and hatred. Institutionalised principles of colonial rule have led to post-colonial

⁶⁶ Lyons, Claire L., and John K. Papadopoulos, eds. *The archaeology of colonialism*. Vol. 9. Getty Publications, 2002.

⁶⁷Rahman, Aziz, Mohsin Ali, and Saad Kahn. "The British art of colonialism in India: Subjugation and division." *Peace and Conflict Studies* 25.1 (2018): 5.

governments employing colonial tactics and policies to seize and hang onto power. The present use of the colonial sedition laws and the further incitement of religious violence for vote banks speaks to the enduring legacy of the past on the present.

Conclusion

Colonization has transcended the 20th century and continues to affect the world tangibly even today. It has resulted in skewed power structures globally and institutionalised inequalities domestically. The impact of colonial rule can be seen in India today, decades after its independence, from the laws framed in the constitution to the weaponised hostilities between religious groups. In the global context, the enduring legacy of colonialism persists in the ongoing sectarian violence between religious and ethnic groups originally artificially divided to supplement British conquest. As outlined above, Western hegemony over international bodies-ostensibly intended to provide equal platforms for all nations-is also a direct result of the colonial process. Bretton Woods Institutions like the IMF and the World Bank are funded largely by, and therefore favourable largely to, the Global North. Similarly, neo-colonialism in the 21st century takes direct inspiration from colonial endeavour. American intervention in Vietnam and Latin America are largely reminiscent of the British Raj in India and Africa. The argument against reparations relies largely on the assumption that colonialism ended with the independence of the colonies. However, this assumption ignores the effects of colonialism outlined in this paper. Since colonialism has affected, and continues to impact the socio-economic and political spheres of colonies, the onus falls on colonial powers to repair the damage that they created.

The Relationship Between Cognitive Processing (Rumination) and Posttraumatic Growth Among Vietnamese Young Adults in the Covid-19 Pandemic By Hieu Lam Nguyen

Abstract

The viral COVID-19 pandemic has struck the world for over two years, but despite the psychological consequences coming along with this pandemic, substantial positive changes can still be witnessed in the aftermath of this traumatic event. Post-traumatic growth (PTG) refers to positive psychological changes upon re-evaluating traumatic events and developing a new, positive life narrative. In this study, sixty-one participants were assessed in March 2022 to examine the relationship between cognitive processing, specifically rumination in both forms (intrusive rumination and deliberate rumination), and post-traumatic growth among Vietnamese young adults during the COVID-19 pandemic. The results revealed that intrusive rumination can elicit subsequent deliberate rumination that is likely to be related to eventual PTG since it is conducive to rebuilding the understandings of the world, the self and others.

Introduction

11 March 2020 marked the day the World Health Organization (WHO) announced the outbreak of COVID-19 to be a global pandemic. (1) Two years after that, there have been 450.229.635 confirmed cases of COVID-19 worldwide, including 6.019.085 deaths by 1 March 2022. (2) The complexity and novelty of the viral pandemic have resulted in a tremendous number of psychological challenges among the global community. Psychiatric symptoms, including post-traumatic stress disorder (PTSD), depression, anxiety, insomnia, and obsessive-compulsive symptoms are common among COVID-19 survivors. (3) According to WHO, the COVID-19 pandemic has triggered a massive 25% increase in the prevalence of anxiety and depression worldwide (4), exerting a major impact on the healthcare system, the economy, and the society.

Despite the psychological consequences of traumatic experiences, an increasing number of researchers have shifted their focus to studying whether and how people can grow through the challenges. Post-traumatic growth (PTG) is defined as a positive psychological change upon re-evaluating traumatic events and developing a new, positive life narrative. (5) Substantial positive changes have been witnessed in various contexts, ranging from earthquakes (6) (7) to

terrorist attacks. (8) PTG is negatively associated with both depressive symptoms (9) and emotional distress (10) but positively associated with quality of life. (11) Studies of post-traumatic growth play an important role in more robustly comprehending the potential reactions to trauma and adversity, rather than focusing solely on the negative consequences. (12)

Cognitive processing refers to a set of operations involved in the production and manipulation of mental representation of information. (13) Cognitive processing could be indicated as a central factor in the development of PTG. (14) Rumination is defined as the cognitive process of having repetitive thoughts about traumatic events and their consequences. (15) In this study, I concentrated on both maladaptive and adaptive types of rumination: intrusive rumination and deliberate rumination. (16) Intrusive rumination is characterized by automatic and negative thoughts about the event, while deliberate rumination is associated with intentional and purposeful thoughts about the event. When rumination is intrusive, people have been known to have difficulty adjusting to the circumstance, leading to increased degrees of depression and posttraumatic stress. (17) People who can engage in intentional, meaningful cognitive processes, on the other hand, can focus on the positives even when faced with uncertainty. Even though the previous studies have demonstrated that individuals may engage in maladaptive rumination with an aim to handle stress in relation to COVID-19 (18), it is also possible that participants may indicate increased deliberate rumination as social distancing and quarantine allowed more time for self-reflection.

As of 27 March 2022, WHO Vietnam released a situation update of the current community outbreak in Vietnam. A total of 1,053,425 new cases and 441 new deaths were reported from 21 - 27 March 2022 (19). With around 98% of patients being monitored at home and nearly 77.7% of the total population having received two vaccination doses, the situation still remains stable even though the number of COVID-19 cases is increasing. One of the very few research on the psychological impacts associated with COVID-19 was conducted in February 2020 to examine the impact of social distancing on the quality of life and economic well-being among 4029 Vietnamese citizens (20). People with COVID-19 were more likely to report depressive symptoms and lower health-related quality of life. Attaining a higher level of education (undergraduate degree or above) and maintaining a healthy lifestyle (e.g., engaging in physical activity, abstaining from alcohol consumption, and having healthy diets) were reported to be highly associated with a lower risk of depression and higher quality of life during the

COVID-19 pandemic. Individuals who are married, older people, and women reported lower health-related quality of life compared to the remaining groups.

Vietnam is among the most vulnerable countries to COVID-19 on both economic and health metrics. The emergence of the COVID-19 continues to generate substantial distress. It is of importance that the awareness of the potential for positive change in the citizens following trauma and adversity should be heightened in Vietnam, since it can be used as foundations for further therapeutic work that trauma can be overcome (20). Very few researchers have investigated the subject of PTG, and no studies, to my knowledge, have been constructed in Vietnam to investigate the variables associated with PTG. Little is known about how post-traumatic growth may develop from Vietnamese citizens' pandemic experiences. This study is the first study designed to examine posttraumatic growth among Vietnamese young adults in Vietnam. This study aims to provide empirical evidence about the impacts of cognitive processing, specifically rumination, on the potentiality of post-traumatic growth among Vietnamese young adults during the COVID-19 pandemic.

Materials and Methods

2.1. Recruitment and Participants

Eligible participants consisted of 56 Vietnamese young adults aged from 18 to 25 years of age, living in Vietnam during the COVID-19 pandemic. Individuals who cannot read and understand Vietnamese or do not have access to the internet were excluded from taking the survey. Participants were recruited via social media (e.g., Facebook groups and Reddit).

Demographics

The demographics questionnaire was designed by the researcher. Participants were asked to respond to questions about gender, marital status, education, employment during pandemic, monthly household income, current living status.

COVID-19 Exposure Scale (National Centre for PTSD)

COVID-19 exposure of the participants was measured based on a 28-item self-report measure to assess potentially traumatic exposures associated with the COVID-19 pandemic. Participants answered based on YES or NO responses to the items addressed in the scale (e.g. "I

became sick with COVID-19, but symptoms were not severe”). The scale was scored cumulatively by summing the number of “Yes” responses with the range from 0 to 28; higher score equals more exposure. Individual items were used independently to characterize different types of exposure to COVID-19 stressors.

Primary Care PTSD Screen for DSM-5 (PC-PTSD-5)

Individuals with probable PTSD in primary care settings were identified by using a 5-item Primary Care PTSD Screen for *DSM-5* (PC-PTSD-5). The measure begins with an item assessing lifetime exposure in relation to traumatic events. If a respondent denies exposure, the PC-PTSD-5 is complete with a score of 0. However, if a respondent indicates that they have had any lifetime exposure to trauma, the respondent will respond to 5 additional yes/no questions about how that trauma exposure has affected them over the previous month. The respondents can score a 0-5 on the PC-PTSD-5 which is a count of “yes” responses to the 5 questions. The highest score a respondent can get is 5, and the lowest score is 0.

The Event-Related Rumination Inventory (ERRI)

Daily intrusive and deliberate rumination related to COVID-19 were measured using the Event-Related Rumination Inventory. Participants were instructed to answer on a 3-point scale. ERRI consists of 2 sub-scales: intrusive rumination (e.g. “I could not keep images or thoughts about the event from entering my mind.”) and deliberate rumination (e.g. “I thought about whether changes in my life have come from dealing with my experience”). There are 10 items for each subscale, running from 0 (not at all) to 3 (often) with the maximum score of 30 and the minimum score of 0 for both scales.

Posttraumatic Growth Inventory-Short Form (PTGI-SF)

The 10-item short form of the Posttraumatic Growth Inventory was adopted to assess daily PTG as a result of COVID-19. The participants were instructed to answer based on their experience with the pandemic. Each item in this scale was answered based on a 6-point response running from 0 (e.g. I did not experience this change as a result of COVID-19) to 5 (e.g. I experienced this change to a very great degree as a result of COVID-19). The PTGI includes 5 subscales for a total of 10 items: Relating to Others, New Possibilities, Personal Strength,

Spiritual Change, and Appreciation of Life. The scale has a minimum score of 0 and a maximum score of 50; higher score equals higher level of PTG.

2.3. Procedure

The survey started on February 19 and ended March 11, 2022. Participants who identified as 18 - 25 and reported living in Vietnam were recruited to take part in the study via an online survey. The survey link was posted on social media platforms, and the participants completed the survey online. All participants were provided with a brief description of the study and instructions on how to complete the survey. All study instruments were translated into Vietnamese by the researcher, a native speaker of the language. The Vietnamese translations were piloted with native Vietnamese speakers prior to the deployment of the public-facing survey.

Results/Demographics

Among the 61 participants (Table 1), more than half (63.9%) identified as female. The majority (96.7%) of participants were single. The sample was well-educated, with 82% reporting some university education. Given the target age range for the sample, it was not surprising that over half (60.7%) of the respondents were currently full-time students. The median monthly household income was reported as less than 5 million VND, which is in the range of population average monthly income: 4.2 million VND. The majority of individuals (72.1%) were living with their family (parents, siblings, grandparents).

Trauma Exposure

Twenty two participants (36.1%) had been confirmed positive with COVID-19; among whom, three (4.9%) had been intubated or on a ventilator. 14.8% of participants had family members or friends who died of COVID-19. Among 61 participants, 54.1% of them were reported to have experienced a previous traumatic event, while 31.2% of participants exhibited possible PTSD based on scores from the PC-PTSD-5.

Table 1. Categorical Variables		
	N (total = 61)	%

Gender		
Male	20	32.8
Female	39	63.9
Prefer not to say	2	3.3
Marital Status		
Single	59	96.7
Married/Living with Partner	2	3.3
Education		
Less than a high school certificate	4	6.6
High school certificate	7	11.4
Bachelors	50	82
Post-graduate degree	0	0
Employment During Pandemic		
Employed Full-time	7	11.4
Employed Part-time	17	27.9
Unemployed	0	0
Student	37	60.7
Monthly Household Income		
< 5 million VND	32	52.5

5 - 10 million VND	14	22.9
10 - 15 million VND	7	11.5
15 - 20 million VND	3	4.9
> 20 million VND	5	8.2
Current Living Status		
I live alone	6	9.8
I live with friends	9	14.8
I live with my partner	2	3.3
I live with my family (parents, siblings, grandparents)	44	72.1
Had COVID		
Yes	22	36.1
No	39	63.9
Hospitalized with COVID		
Yes	3	4.9
No	58	95.1
Put in ICU Due to COVID		
Yes	3	4.9
No	58	95.1

Intubated or On Ventilator		
Yes	3	4.9
No	58	95.1
Family or Friend Was Hospitalized		
Yes	35	57.4
No	26	42.6
Family or Friend Died of COVID		
Yes	9	14.8
No	52	85.2
Reported a Previous Traumatic Event		
Yes	33	54.1
No	28	45.9
Met Criteria for Possible PTSD		
Yes	19	31.2
No	42	68.8

Table 2. Continuous Variables		
	Mean	SD
COVID Exposure Scale (CES) Total		
CES Self	1.1	1.7

CES In Home	1.6	1.9
CES Outside Home	2.5	2.1
CES Work	1.7	1.3
Intrusive Rumination	12.5	7.1
Deliberate Rumination	14.9	7.6
Post-Traumatic Growth Inventory	25	10.9

Table 3 indicates the intercorrelations among key variables. A Pearson product-moment correlation coefficient was computed to assess the relationship between PTG and its subscales, and rumination. Most significantly, intrusive rumination was strongly associated with deliberate rumination ($r = 0.73, p < 0.01$). While having a weak correlation with intrusive rumination ($r = 0.41, p < 0.01$), PTG was found to be moderately positively associated with deliberate rumination ($r = 0.59, p < 0.01$). However, the relationship between both forms of rumination and PTG was significant, indicating that rumination was statistically associated with PTG.

Table 3. Correlation Table							
	CES Total	CES Home	CES Outside	CES Work	Intrusive	Deliberate	PTGI
CES Total	X	X	X	X	0.34**	0.18	0.15
CES Self	X	0.77**	0.53**	0.30**	0.06	0.01	0.02
CES Home	X	X	0.59**	0.45**	0.17	0.08	0.03

CES Outside	X	0.59**	X	0.38**	0.37**	0.2	0.26*
CES Work	X	0.45**	0.38**	X	0.47**	0.27*	0.07
Intrusive	0.34**	0.17	0.37**	0.47**	X	0.73**	0.41**
Deliberate	0.18	0.08	0.2	0.27*	0.73**	X	0.59**
PTGI	0.15	0.03	0.26*	0.07	0.41**	0.59**	X

* = $p < 0.05$; ** = $p < 0.01$

Table 4 demonstrates the relationship between each subscale of PTG and rumination. Both intrusive and deliberate rumination were statistically significantly correlated with all domains of the PTG. Spiritual Change has the strongest correlation with both intrusive ($r = 0.61$, $p < 0.01$) as well as deliberate rumination ($r = 0.65$, $p < 0.01$), while Relating to Others exhibited the weakest, though still positive, correlation with intrusive ($r = 0.23$, $p = 0.75$) and deliberate rumination ($r = 0.45$, $p < 0.01$). Personal Strength, Appreciation of Life, as well as New Possibilities were also positively associated with rumination.

Table 4: Correlation between Rumination and each domain of PTG					
	PTGI I - Relating to Others	PTGI II - New Possibilities	PTGI III - Personal Strength	PTGI IV - Spiritual Change	PTGI V - Appreciation of Life
ERRI - Intrusive	0.23	0.25	0.35**	0.61**	0.36**
ERRI - Deliberate	0.45**	0.46**	0.54**	0.65**	0.50**

* = $p < 0.05$; ** = $p < 0.01$

3.2. Equation

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

Where x, y are the row variable and the column variable, respectively.

4. Discussion

This study examines the association between two kinds of rumination, deliberate and intrusive, on the post-traumatic growth of young Vietnamese adults during the COVID-19 pandemic. It is found that intrusive and deliberate thoughts play different roles in impacting the outcomes following a traumatic experience. Intrusive rumination can elicit subsequent deliberate rumination that is likely to be related to eventual PTG since it is conducive to rebuilding the understandings of the world, the self and others (25).

The study was conducted during the time community transmission of COVID-19 has recently surged both at national and provincial levels; however, Vietnam continues to move forward with sustained management of COVID-19. The majority of the population has been vaccinated which may result in reduction in mortality trend as well as perceived severity compared to the previous heights of COVID-19. (26) Furthermore, the majority of participants in this study were not among the most vulnerable group in the COVID-19 pandemic, consisting of young adults. Additionally, the two-year experience of COVID-19 might have acquainted the local public with preventative measures to protect themselves from the current situation of COVID-19. At the time the survey was administered, the perceived severity of COVID was potentially lower than at other points during the pandemic. As a result, the participants' recollection of pandemic-related events may have been influenced. However, the study was designed with questions which do not refer to any specific timeframe during the COVID-19 pandemic, rather allow the respondents to freely reflect on their experience with COVID-19 as a whole. Data collection in this study was performed 2 years after the beginning of the pandemic and 2 months after the last height of pandemic in Vietnam. The longer the time since the critical event, the greater the extent of PTG that is reported (27); however, it is likely that the intervening events and processes influence PTG, rather than the passage of time.

Young respondents are generally more likely to report PTG once a given level of developmental maturation was achieved (28), so this can also influence how traumatic events are cognitively processed. High levels of education and income can also be two facilitators for PTG. The majority of participants achieved a high level of education and had the amount of income in or above the range of average monthly income per capita in Vietnam. Past studies have suggested that higher levels of education and income were associated with more PTG (29). This can be one of the reasons that PTG occurred to the sample.

Intrusive rumination during the COVID-19 pandemic positively associates with PTG tendency among the participants. This was surprising given that it is inconsistent with other studies showing that intrusive rumination either soon after the traumatic event or recently was weakly associated with PTG (30). A possible explanation for these results is that intrusive rumination disrupted PTG by causing the individuals to focus on the negative aspects of the traumatic event, having them repetitively engage in unintentional thinking related to the traumatic event. In our sample, however, we found that intrusive rumination was positively associated with both deliberate rumination and post-traumatic growth. It is possible that, in young adults, intrusive rumination serves as a precursor to or opportunity for deliberate rumination, facilitating post-traumatic growth. However, given that the survey was administered two years into the pandemic, it is possible that recall bias is impacting this result. Additionally, post-traumatic growth is, in part, driven by an individual's subjective experience and perception of the traumatic event in question (helplessness, controllability, life threat). The COVID-19 pandemic differed from other traumatic events often studied in the literature in that it was long-term and widespread. During the pandemic, the greater public was introduced to public health measures that could be used to reduce the spread and lethality of the virus, such as masking, social distancing, etc. It is possible that these measures, combined with the fact that our sample was in a lower-risk age group, resulted in a less traumatic experience for our population of interest. The positive relationship between intrusive rumination and PTG can be assumed to be because they have set the stage for further cognitive processing rather than because they have influenced PTG. Previous studies also suggested that continued intrusive rumination can expose people to traumatic cues and thereby encourage further cognitive processing of traumatic events as well as stimulate attempts to engage in more deliberate processing of the experience (31). It is possible that intrusive rumination does not resolve cognitive discrepancies after a traumatic

event, but it can elicit subsequent deliberate rumination that is conducive to the reconstruction of the understanding of the posttraumatic world and the benefits of the process. It is deliberate rumination that is associated with eventual PTG (32).

Deliberate rumination is found to most be correlated with the current extent of PTG. This finding is consistent with previous studies, suggesting the central role of deliberate rumination in processing the traumatic experience, ultimately leading to the identification of positive changes after the event (33), (34). It is possible to propose that deliberate rumination has other psychological processes involved and, thus, promotes PTG by allowing the reconstruction of shattered assumptions at the time of trauma and overcoming its negative consequences. A shift in perception of trauma and PTG can be achieved by focusing on the search for meaning and positive aspects of the experience. Facilitating the construction of deliberate rumination can promote the cognitive processing of the individuals, resulting in higher posttraumatic growth tendency and laying foundations for further therapeutic work by providing hope that trauma can be overcome.

Understanding of reactions to trauma and adversity should take into consideration the potential for PTG if it is to be considered comprehensive. The past uncertainty of the COVID-19 pandemic has revealed significant concern for mental health, traumatic consequences, and stressors among citizens in Vietnam. Further investigation of the possible positive outcome in the aftermath of a traumatic event can facilitate PTG which may be considered a legitimate therapeutic aim.

Limitations and Strengths:

There are still limitations which need to be acknowledged in order to improve the validity of further studies and clarify the factors influencing post-traumatic growth. First, the relatively small, convenient sample of participants is not representative of the general population. The non-random sampling may have also resulted in sampling bias which influences the generalizability of the results. My sample primarily consisted of college students and highly educated people with access to technology. Only about 28.3% of the population in the age range of 18 to 29 was university-educated (35), which indicated that the sample is not representative of the population. Second, the cross-sectional nature of the study limits the accuracy of the conclusions that can be drawn. Although the data can be described at one point in time, the

direction of the relationships between these variables is less clear. Based on our cross-sectional data, we are unable to determine if rumination preceded post-traumatic growth within the population. Third, the recall bias might not be wholly eliminated in the study, and the accuracy and volumes of memories related to posttraumatic growth may be greatly influenced by other undefined factors. Fourth, all demographics and psychological variable data were self-reported by the participant which potentially led to reporting bias. For instance, the respondents may exclude their financial support from their family, since the majority of participants are college students, when reporting on their monthly income which can lead to inaccuracy of the provided information.

Despite these limitations, to my knowledge, this study is among the first to examine the cognitive processing, specifically rumination, influences on post-traumatic growth among Vietnamese young adults during the COVID-19 pandemic. Furthermore, this study contributes new knowledge to previous theoretical and empirical studies of the relationship between rumination and PTG that have suggested a positive association between these two variables. From health-enhancement and intervention perspectives, this study may have possible clinical implications: rumination and timing may have to be considered to fully understand how and whether or not PTG is existing. This study also highlights important implications for young adults undergoing traumatic experiences of the COVID-19 pandemic. Identifying and supporting people's ruminations that are constructive and deliberate, could significantly enhance the success of coping with highly distressing and traumatic events as well as experiencing positive effects of PTG.

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Major Controversies of Cryptocurrencies By Zhiyang Zhong

Abstract

Designed to partially replace the traditional global financial system, Bitcoin arrived with great fanfare on the world stage in 2008. Friedrich A. Hayek suggested, in 1976, that the public needed relief from the absolute state monopoly over the money supply and reliance on the government for maintaining a stable value of money. Such observations may have helped inspire the inventors who generated the ideas for cryptocurrencies. The launch of Bitcoin provoked an intense debate over its functions as a currency and its role in the financial system globally. This paper attempts to explore the major controversies associated with the most popular cryptocurrency Bitcoin and shed light on the potential threats it has posed to the economy and society.

The Invention of Bitcoin and Its Contributions

Driven by dissatisfaction with the monetary and banking systems after the 2008 crisis, Satoshi Nakamoto designed Bitcoin as a virtual currency that would rely on blockchain technology (Monrat et al., 117134-117151). The blockchain allows Bitcoin users to make peer-to-peer transactions without official third-party institutions that keep track of the history of every transaction in a secure set of encrypted blocks (Farell). By setting blockchain as the foundation of its monetary system, Bitcoin claims to provide users with a safer, easier, and faster way to save and transfer value than those offered in banks and other financial institutions. Nakamoto limits the total amount of Bitcoin, enabling the Bitcoin system to be decentralized without the control or intervention of any central government. Bitcoin is meant to eliminate the “trust” required in the current money system and replace the reserve currency that people now rely on (Nakamoto).

Bitcoin has brought innovative technology and perspectives for people to reflect on the function and value of the existing currency system, which may contribute to an evolution of the system. Back in 1976, Hayek proposed taking the monopoly of money issuance away from the government to maintain the stable value of money with the help of competition. The creation of Bitcoin marks the appearance of a series of new ideas about how money ought to be. The decentralized financial system using blockchain is still at its early stage, and people believe that

blockchain can be applied to other fields (Al-megren et al., 1417-24). The consistent innovation and development of blockchain technology may bring some brilliant ideas that can be applied to the current financial system.

Additionally, the anonymity offered by Bitcoin provided better options for people living in countries with repressed economies, such as Argentina and Venezuela (Kethineni et al., 141-57; Cifuentes, 99-116). With proper regulations, Bitcoin offers more convenient international trade options because it is designed to be a universal currency that eliminates currency exchange, bringing trade globalization to a different level (Ganne).

Nevertheless, a number of the other arguments favoring Bitcoin, upon closer examination, fall apart. Bitcoin is not necessarily a curse, nor is it as beneficial as its defenders claim when compared to the reserve currency system we have now.

Bitcoin's Potential as a Reserve Currency

Exchange methods evolved from barter to fiat money through the prevalence of hard currency, coinage, and the gold standard (Davies). From the Dutch Guilder to the British Pound and the United States Dollar (USD), reserve currencies did their job well (Dalio). In most cases, people freely use currencies when countries that issued them remain economically and diplomatically strong. For example, banks around the globe hold large amounts of USD, enabling easy international transactions (Goldberg, 2-5). Although there is no single international currency, the dollar essentially serves this role. When the financial condition of a country declines significantly, people start doubting its ability to maintain the stable value of its currencies and switch to currencies that are issued by more financially sustainable countries. With this cycle, a reserve currency will always prominently remain in the financial market, allowing most people to use it as a widely-accepted payment in transactions (Dalio). In an ever-changing financial system that always has stable reserve currencies available for transactions, switching to Bitcoin has no obvious necessity.

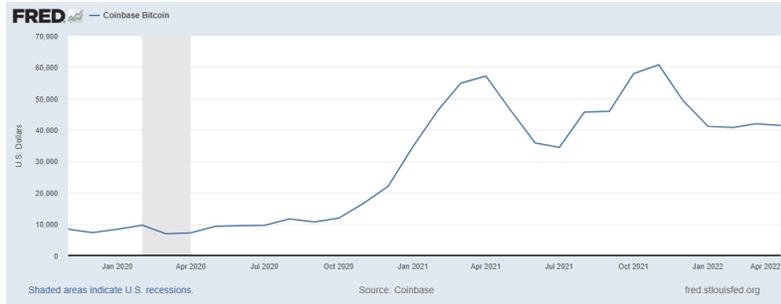
Bitcoin's Position as a Store of Value

Turning to Bitcoin's practicality, it barely fits the definition of money that British economist William Stanley Jevons devised in 1875, later supported by Carl Menger, Ed Dolan, and Greg Mankiw. Analyzing how Bitcoin functions as a store of value, the standard of

accounting, and the medium of exchange, we found that it is an inferior form of “money” compared to prominent reserve currencies that we have now and in the history.

As a store of value, for example, Bitcoin leaves much to be desired. Speculation drives its price, and the value of a Bitcoin is mercurial. Bitcoin simply cannot serve well as a store of value because of its high price volatility. For instance, Bitcoin increased 623% in value from November 1st, 2020, to November 9th, 2021, then decreased by 45% from November 9th, 2021, to April 1st, 2022 (Coinbase). While the value of major currencies such as USD, GBP and CNY, fluctuate due to inflation, international trades and other factors over time, historically the rate of change remains much more stable and lower than that already exhibited by Bitcoin. Observations of the Consumer Price Index (CPI) between the outbreak of Covid-19 in November 2019 and April of 2022 evidence only a 0.07% decrease in prices followed by an increase of 12%, suggesting that the dollar, even in a major crisis of an epidemic, is a far more stable currency (U.S. Bureau of Labor Statistics). For a longer period, USD has generated a change of 609% in roughly 51 years since the United States abandoned the gold standard, while Bitcoin could generate this change in less than a year (Coinbase; Gavin 15).

Furthermore, the place in which people store Bitcoin needs to be evaluated, and the security of the crypto wallet remains a crucial concern. Unlike a bank where people deposit money into accounts, a decentralized money system means users must carefully monitor the value they possess in a crypto wallet. People are more vulnerable to suffering a value loss in a Bitcoin hack than losing dollars in a bank robbery (Kaushal et al., 172-77). In the case of the current financial system, governments can ensure deposits in regulated banks, for example, by establishing the Federal Deposit Insurance Corporation (FDIC). Bitcoin users, however, are supposed to take full responsibility for their value lost because issuance for crypto assets is limited, according to Brian O’Connell, an insurance analyst at Insurance Quotes (Cabello). The volatility of Bitcoin and the security problem of Bitcoin wallets together indicate that Bitcoin is an unsafe and uncertain way to store value.



Bitcoin price from November 2019 to April 2022, from FRED



Consumer Price Index from November 2019 to April 2022 from FRED

Bitcoin’s Function as a Standard of Accounting and Medium of Exchange

Bitcoin’s function as a standard of accounting performs worse than the USD. The price of goods in terms of Bitcoin will fluctuate even without changes in supply or demand because the value of Bitcoin is volatile. Using a quickly-changing currency to measure the market value of goods, services, and other transactions, sellers lose money if they fail to adjust to the changing value of the currency. On the other hand, if sellers adjust the price of goods consistently, the frequent price change will induce menu costs, making the Bitcoin-based financial system costly to society (Sheshinski and Weiss, 287-303). The USD, the current reserve currency, also induces menu cost, but with a slow inflation rate, the menu cost is not so significant as that of Bitcoin (FRED). Although one can argue that Bitcoin develops a more accurate measurement of money – with the smallest unit Satoshi = 0.000,000,01 BTC – a straightforward calculation disproves this argument (CNBCTV18; Tasca 1-6). If Bitcoin is replacing the USD, a Satoshi will be worth \$0.011, calculated using the current amount of Bitcoin (Best; FRED; Buckho). Since a US cent is worth \$0.01, the so-called precise unit of Bitcoin does not even meet the current accuracy of the USD. This level of precision is ignorable and unnecessary in a modern economy, as the penny has limited usage, and so will a Satoshi.

Regarding the final definition of money given by Jevons, the high volatility of Bitcoin makes it harder to use as a medium of exchange, and the mining system it is based on makes the transaction costly. The buyers suffer if the money they hold suddenly depreciates, making it cost more Bitcoin to purchase an item. The sellers' lives will not be made easier if they receive money representing half the value it held the day before. The uncertainty regarding Bitcoin's value explains why it is only used by a few corporations or institutions, further complicating its day-to-day use (Kewell, 491-98).

The Negative Externality of Generating Bitcoins

The process of generating Bitcoin poses a negative externality to society as it requires significant energy consumption. Bitcoin is based on the Proof-of-Work (PoW), and "mining" is the foundation of the Bitcoin system (Kroll et al., 1-11). In a transaction, "miners" use colossal computing power to solve a difficult algorithm. The first miner who solves the algorithm will broadcast to all nodes in the Bitcoin blockchain system and get some Bitcoin as a reward. With the increasing popularity of Bitcoin, energy consumption and electricity use is soaring (CCAF). When deciding whether to mine Bitcoin, miners consider the electricity cost, mining farm cost, and the awards or coins they will get (Kroll et al., 1-11). What generates externality is that miners make decisions without considering environmental pollution. The Bitcoin system generates both technical and pecuniary externality, though the latter does not induce deadweight loss (Murphy; Mankiw; Viner). The current banking system, nevertheless, does not produce as much external cost as Bitcoin does.

To visualize the externality generated by Bitcoin mining, total private cost and social cost are calculated using the data of Bitcoin's energy consumption, average electricity price, amount of carbon emission, the average cost of Bitcoin miners, amount of Bitcoin miners, and average life-span of miners. The social cost per transaction of Bitcoin is then roughly \$34, compared to essentially zero for the USD (Vries et al., 498-502; Rennert and Kingdon; Jain; Buy Bitcoin Worldwide; Blockchain). Few people are aware of the amount of social cost now since the current extent of Bitcoin transactions is limited. The situation will only be more severe as Bitcoin spreads its influence. When the cost burden pressed by Bitcoin starts impacting most people, it will significantly drive down the demand in the market, causing a recession and damaging the economy.

Mining Bitcoin also causes the pecuniary externality by inducing rising electricity costs (Counts, as it requires a huge amount of electricity, pressing the cost burden on electricity and consumers who neither mine nor trade Bitcoin (O'Dwyer et al., 280-85). Studies by the Matteo Benetton, Adair Morse and Giovanni Compiani reveal that households paid an “additional \$165 million a year in energy costs, while businesses paid an extra \$79 million” in upstate New York due to Bitcoin mining’s energy consumption (Benetton et al., 14-18). The electricity wasted by Bitcoin mining not only drives up prices but also induces the misallocation of resources. In addition to the electricity consumption, time spent on maintaining mining equipment and hardware & software & building used for mining generate opportunity costs and the waste of resources, as Bitcoin itself fails to benefit society by effectively using these resources (Williamson 107-15; Wieser). Resources are occupied, and the market can only allocate resources to people who can convert them into productivity at a higher price. It decreases the supply of other goods and services in the market, driving the overall price up and making people’s lives more expensive.

Consequently, considering its externality and misallocation, Bitcoin’s usage in transactions will be costly for society, compared to the reserve currencies which people already adopted. Bitcoin will only generate more inefficiencies and external costs if it becomes more widely used and replaces the current money system, making it not a blessing but a catastrophe for society.

Conclusion

To conclude, despite the creation of the meaningful decentralized financial transfer system, Bitcoin is unlikely to serve as an absolute blessing and the “revolutionary hero” of the economy. Traditional reserve currencies can still deliver the main functions of “money” more efficiently than Bitcoin as they are more suitable as stores of value and mediums of exchange without producing external costs to society. Bitcoin is more accepted as an innovative form of currency, but it can still hardly replace the significant role that major currencies have in the current financial system.

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Is Bitcoin a Blessing or a Curse? By Zhuoer Zhao

Introduction

In early 2022, the cryptocurrency market suffered a radical downward dive. According to CNBC, “the overall market capitalization of crypto assets has dropped to less than \$1 trillion from its November 2021 peak of \$3 trillion. It is the first time since 2021 that the asset class has been worth less than \$1 trillion.” Many warned that this is the moment we have been waiting for when the weaknesses of cryptocurrencies are exposed, while the intrinsic value of the cryptocurrencies remains unclear. Some investors hold the belief that the trading value of bitcoins might fall even further as “a recession and possible ‘crypto winter’” is around the corner (Reinicke). Indeed, a number of currencies in the crypto market have nearly been wiped out. Stablecoins have fallen extremely precipitously, and Tether (USDT) in the Stablecoin family has lost so much value that the tokens are now valued less than the dollar (Chaturvedi). On the contrary, Bitcoin is expected to gather strength for a new round of value increases and utilization around the globe. Overall, the strength of cryptocurrency can be mainly attributed to the dependence on blockchain, the accessibility, the irreversible nature of the system, the continuously improving regulations, and the competition of currency that it induces.

The Dependence on Blockchain Technology

Bitcoin, an invention of modern technology, is based on blockchain technology. As Marc Andreessen stated, “Bitcoin gives us, for the first time, a way for one Internet user to transfer a unique piece of digital property to another Internet user, such that the transfer is guaranteed to be safe and secure” (Böhme et al. 225). From the emergence of Bitcoin, people started inquiring about how Bitcoin works and is utilized. Blockchain, the technology that sets the foundation of Bitcoin, is a digitized, decentralized, public ledger of all cryptocurrency transactions. Blockchain creates and shares all online transactions by storing them in distributed ledgers as a data structure on a computer network. It validates transactions using a peer-to-peer network of computers and allows users to make and verify transactions immediately without a central authority (Niranjanamurthy et al. 1). Overall, a blockchain is a network that connects individuals and an immense database containing all past transactions and information modification. The entire cryptocurrency system is based on blockchain technology, and Bitcoin greatly took advantage of

blockchain to generate its advantages in accessibility, anonymity, transparency and decentralization.

Accessible Method of Currency Exchange

One of the major advantages of Bitcoin is that it is easily accessible globally and thus is a highly versatile currency. It takes only minutes for a user to transfer money, and Bitcoins can also be exchanged for other currencies at any time. The accessibility of Bitcoin renders it convenient for people to exchange currencies without paying a fee (*“Pros and Cons of Bitcoin”*). Moreover, unlike conventional banking systems which provide users with bank accounts, Bitcoin users have their numerical codes and public keys which prevent public tracking and further confirm the anonymity of users. Protective solutions also exist for users if their information has been exposed. Users can generate a new wallet address to protect their Bitcoin account and maintain anonymity (*“Pros and Cons of Bitcoin”*). In modern society, people increasingly value privacy which Bitcoin facilitates. No specific personal information is required to exchange for Bitcoins and manage transactions. Moreover, due to Bitcoin’s decentralization trait, no central party such as banks exists which greatly strengthens user autonomy (Reid et al. 5).

Based on the aforementioned advantages, it is evident that Bitcoin is a novel and efficient approach to transactions and has great future potential. As the world is undergoing rapid technological innovation, means of currency exchange are likewise swiftly evolving. From the historical barter trade to the emergence of currency, an important pattern emerges: currency evolution inevitably moves towards more advanced and greater scientific efficiency. Consequently, cryptocurrencies including Bitcoin are the next development after cash and will not disappear easily.

The Irreversible Nature of the System

The decentralized nature of Bitcoin, which separates itself from the central authority, lie central to this controversy of Bitcoin. Some argue that the lack of regulations and authorities implemented upon Bitcoin encourages more illegal activities, including drug, sex, arms trafficking, and illegal animal trading, while there is also insufficient protection against hackers that will occasionally steal from Bitcoin accounts. Without a central party, one has nowhere to retrace the money.

However, the irreversible trait of the cryptocurrency system can also provide security for the financial system and society to some extent. The free banking system, which shares the similar ability of freely increasing currency supply with cryptocurrency, is an example. Early in the pre-Civil War era, the free banking system existed. “Anyone with sufficient funds was able to open their own bank and issue their own notes, similar to the freedom available to a programmer who adds to the supply of crypto through mining.” (Tong et al.) Many economists do not approve or recognize these free banking systems, especially without government regulation, because they open up greater opportunities for fraud and suspensions of redeemability, which will result in periodic financial crisis (White). However, there were countries such as Canada, Sweden, and Scotland with free banking systems that proved the falsehood in the theory above. According to Lawrence H. White, “when free banking has existed, the interbank clearing system swiftly disciplined individual banks that issued more notes than their clients wished to hold. In other words, redeemability restrained the system as a whole.” As fraudulent bankers were unable to circulate their notes, the irreversible transaction trait, existing in the Bitcoin system, actually is beneficial.

The Regulations on Cryptocurrencies

Due to the significance of Bitcoin in the current financial system, most regulations attempt to sustain Bitcoin (and all cryptos) while reducing the systematic risk it poses. The fact that Bitcoin cannot be controlled by any authority is the reason that regulation is required (Prayogo 5). According to The Institute of Public Affairs, certain policies have already been implemented, including “the easing of exchange rate controls, that have enabled the freer flows of capital across political borders” (Novak). U.S Criminal Law Enforcement Network publishes an annual Bitcoin guide since early 2013 which defines Bitcoin as a currency business, not a currency. The guide places Bitcoin under the Bank Secrecy Act that requires reciprocity and payment processors to fulfill certain responsibilities such as reporting, registration and record keeping (Prayogo 8-9). Ahead of the U.S., some countries have already accepted Bitcoin as a currency, though not publicly used by citizens. Japan already recognizes Bitcoin as a currency since April 2017, while Germany also considers Bitcoin legal (Prayogo 9). Japan is continuously implementing regulations on Bitcoin exchange and learning lessons from the Mt. Gox case. Mt.Gox was a cryptocurrency exchange located in Shibuya, Tokyo (“*Mt.Gox*”). In 2014, the

exchange was hacked, and roughly 740,000 Bitcoin were stolen (Tuwiner). One key feature of the new amendment is that registration is required for the virtual currency exchange service (Ishikawa 128). Furthermore, an amendment to the Payment Services Acts specifically defined virtual currency transactions, which sets the foundation of the regulations of Bitcoin tradings (Ishikawa 126). From Mt. Gox's case, it is clear that the cryptocurrency market is still evolving, and requires more strict regulations to ensure the security and efficiency of the system.

The Initiation of Currency Competition

The rise of cryptocurrencies undoubtedly induces currency competition. Based on Daniel Snaches, "a central proposition in economics is that competition is good" (Snaches). Free markets will find the optimal way to re-organize and rearrange the demand and supply. Therefore, competition between Bitcoin – a private currency – and other currencies is inevitable. Private currencies are units of value issued by a private organization to act as an alternative to a national or fiat currency (Chen). With recent global developments, greater potential exists for private currencies. Recent investigations into private currency competition found that the money supply "will be more accurately set through decentralized provision than by a single monetary authority" (Hogan 4); "allowing multiple issuers of banknotes means that, on average, the market demand for banknotes will match the supply" (4). Thus, the presence of Bitcoins will facilitate more positive currency competition.

Concerns Regarding Volatility

Nevertheless, Bitcoin's volatility has worried the public. Bitcoin's price fell nearly 5% over the last week in the second quarter of 2022 (Gailey). Many are reacting with concern and fear. However, some analysts on Wall Street believe that this is a great chance for Bitcoin to check its system flaws and therefore exclude inadequacy and correct the imperfections. "The collapse of weaker business models such as Terra USD and Luna is likely healthy for the long-term development of this sector," said Alkesh Shah, global crypto and digital asset strategist at Bank of America (Sigalos). The price drop will bestow Bitcoin with an opportunity to rearrange itself and identify possible weaknesses to be corrected, thereby securing long-term potential in Bitcoin and other possible cryptocurrencies.

Conclusion

To conclude, Bitcoin is a blessing to the world in terms of its traits of accessibility, anonymity, transparency and decentralization in the context of the rapidly advancing world and the big data era. More importantly, its dependence on blockchain technology will further bring benefits from the application of blockchain in almost all industries, including food, manufacturing, and healthcare sectors. Bitcoin, as a cryptocurrency and thus an advanced novel technology, is still new to the world and will require improvements in the coming decades. Pinpointing its system flaws, providing improvements, and implementing regulations are crucial to more sustainable development of the system.

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Ending The Opioid Abuse Epidemic Among Construction Workers Through NSAID Therapy and Genetic Screening for CYP2C9 Genetic Variants By Sripada, Sri Kiran

Abstract

Construction labor is a physically intense and strenuous field of work, and thus, many construction workers need analgesics in order to be able to fulfill their daily responsibilities, free from the discomforts and restrictions of inflammation and pain. However, the frequent prescription of opioids for pain relief, especially in high doses and for long periods of time, has fostered an opioid abuse epidemic among construction workers. The detrimental effects on the health of construction workers have been causing construction companies to deal with significant losses on account of absenteeism and decreased productivity. Opioids and other analgesics such as acetaminophen hamper neurological perceptions of pain, while not effectively reducing inflammation which may continue to cause further pain and restriction of movement. This could still allow decreased productivity to prevail among construction workers, leaving the issue of revenue losses in construction companies unresolved or poorly solved. Instead, a solution lies within the prescription of NSAIDs, predominantly metabolized by the CYP2C9 isoform, alongside the CYP2C8, CYP2C19, and other CYP2 isoforms in the CYP450 enzyme family. However, some CYP2C9 genetic variants have been shown to have clinically significant implications in certain people. Thus, a solution lies in personally tailoring construction workers' NSAID therapies via cost-effective genetic screening of their CYP2C9 genotype.

Introduction to the opioid abuse epidemic in the construction industry

Opioids are a highly-addictive class of analgesics used for pain relief. However, certain groups of people are more susceptible to opioid addiction and overdose, with construction workers being a case in point. Construction workers routinely perform physical, strenuous labor in rough, precarious conditions. Thus, construction workers are often prescribed opioids to be able to fully return to and carry out their usual duties. These construction workers then become addicted to opioids, leading to losses of profit for construction companies as a result of decreased productivity and absenteeism from their afflicted workers. The well-being of workers is critical to a successful business. NSAIDs are known for their less-addictive potential compared to opioids, but the risk of NSAID exposure in those with variant phenotypes should be considered.

Therefore, construction companies ought to promote the prescription of NSAIDs while utilizing cost-effective genetic screening for CYP2C9 genetic variants in order to ward off any additional effects of NSAID exposure and toxicity in individuals with mutant phenotypes, thus reducing the number of workers on addictive opioid prescriptions, altogether alleviating the rampant opioid abuse among construction workers that have been responsible for hampered productivity and profits.

Status of the opioid abuse epidemic in the construction industry

Construction work is a very strenuous profession that involves a lot of physical labor in precarious conditions. Therefore, it is no surprise that workers often resort to opioids in order to prevent pain from inhibiting their daily work duties. A long-term study from 2015-18 found that, annually, 42.8% of construction workers complained of chronic musculoskeletal disorders, of whom 24.1% received new opioid prescriptions and 6.3% received long-term opioid prescriptions. Moreover, it was found that, annually, 15% of workers who were prescribed opioids became long-term users. The same study also found that these long-term users were 2 times more likely to develop opioid use disorder (OUD) if prescriptions were high doses (at least 50 MME per day), 4 times more likely if diagnosed with chronic musculoskeletal disorders (MSDs), 7 times more likely if prescribed more than a week's worth of supply, and 10 times more likely if given long-term prescriptions compared to construction workers given opioid medications in lower doses and for shorter durations.^{3,4} Moreover, construction workers have the highest risk of opioid-related death of any occupation. Overdose fatalities among construction workers are 8 times higher than for the general population.² In essence, the higher the dose and the longer the duration of opioid prescription, the higher the chances of developing an opioid addiction, and therefore higher the chances of opioid overdose fatality. These alarming statistics come despite the addictiveness of opioids being widely known.

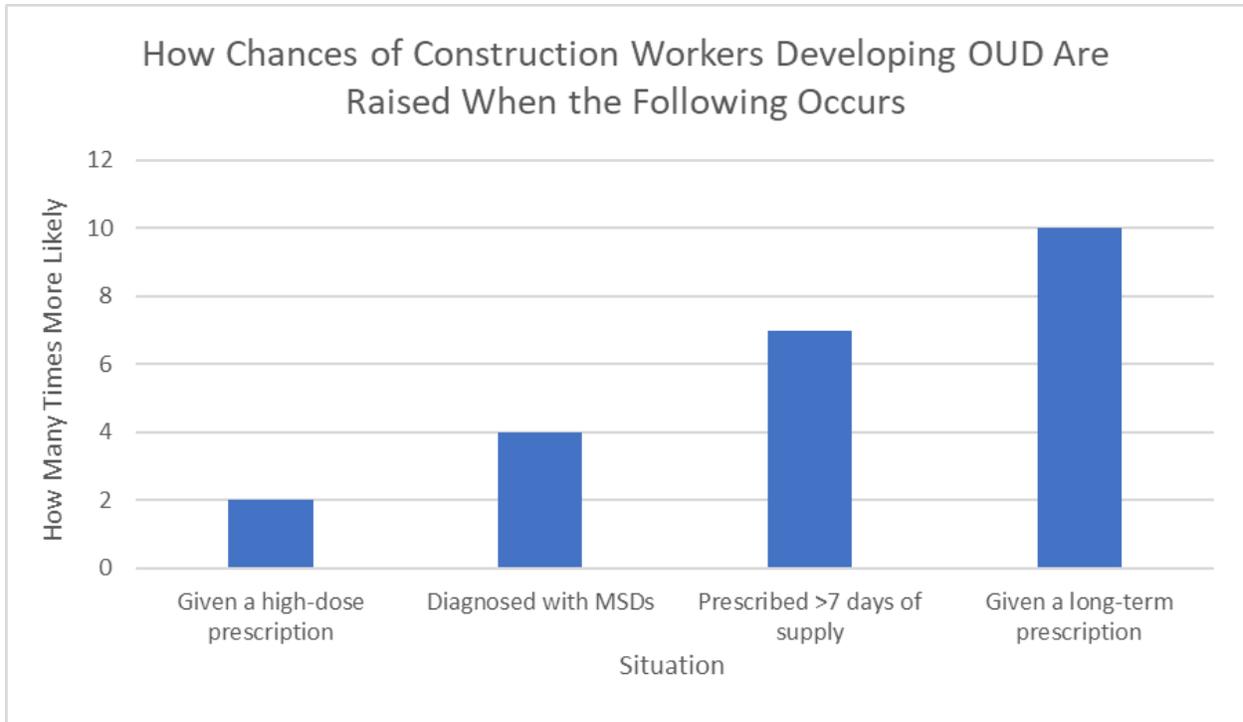


Figure 1. Long-term prescriptions are shown to have increased the chances of construction workers developing OUD by the most, although the fact that a three-year study found that 42.8% of construction workers complained of chronic MSDs raises a great concern that such a proportion of construction workers is at 4 times the normal risk of developing OUD.^{3,4}

Financial toll of opioid abuse in the construction industry

Although construction companies want their workers to perform to the maximum of their abilities, the prescription of opioids to injured workers only worsens the opioid abuse epidemic already rampant in the construction industry. This leads to more workers having to take sick leave on account of the oftentimes debilitating effects of opioid addiction as well as withdrawal. In fact, absenteeism due to chronic illness or injury among the U.S. workforce costs employers about \$530 billion each year. \$198 billion of this is due to diminished productivity from unmanaged or poorly managed chronic health conditions.¹ The continuation of prescribing opioids, especially in high doses, for construction workers with injuries only exacerbates the double effects of injury and addiction on workplace performance, thus being severely detrimental to company profits. The amount of money spent on addiction counseling and other treatments is wasted by the perpetuation of this opioid abuse epidemic.

NSAIDs may supersede opioids in relief from pain and inflammation

The use of NSAIDs for the purposes of pain relief and regaining function carries fewer risks for adverse events and addiction compared to opioids. Treatment with opioids is not superior to treatment with non-opioid medications, namely NSAIDs, for alleviating pain and inflammation-caused hindrance of function over 12 months, a study has suggested. The results do not support opioid therapy for either moderate to severe chronic back pain or hip or knee osteoarthritis pain.¹⁴ This is especially important for construction workers, as a study that surveyed 2,021 construction workers from 2017 to 2018 found that the most common and intense pain spots caused by construction labor were the central and lower back, shoulders, and knees.²⁵ Moreover, a study that conducted 192 trials on 102,829 participants using oral NSAIDs, topical NSAIDs, and opioids to relieve knee and hip osteoarthritis pain and physical function has reported that the oral NSAIDs, topical NSAIDs, and opioids had an 18.5%, 0%, and 83.3% increased risk of dropouts due to adverse events, respectively.¹⁵ As musculoskeletal pain and inflammation continue without any sufficient relief, construction workers would be very much at risk of exacerbating existing injuries and performing work duties with less efficacy, resulting in decreased productivity and company losses. Therefore, this should incentivize construction companies to seek alternative solutions for pain and inflammation relief for their laborers.

NSAIDs are far less addictive than opioids

NSAIDs generally carry no risk of addiction. Despite the potential for some adverse events when taken for long periods, addiction is a negligible risk for those who consume NSAIDs.^{16,17} These findings warrant consideration for a switch towards the use of NSAIDs for pain relief and inflammation reduction to allow construction workers to return to their full capabilities of labor, especially considering the percent of construction workers afflicted with MSDs and their raised chances of developing OUD (Figure 1). The current state of opioid prescriptions often exacerbates existing pain by producing adverse events and addiction, thus contributing to the losses and deficits that construction companies have been facing. However, the individual's CYP2C9 genotype must be taken into account when prescribing NSAIDs to construction workers. Certain genetic variants may result in reduced metabolism of these drugs or adverse drug reactions (ADRs), and thus there must be certain precautions and adjusted procedures to deal with these situations.

Cost-effectiveness of genetic screening

Although genetic screening for each worker's CYP2C9 genotype might appear to be very cumbersome and costly, this procedure is actually quite cost-effective and valuable. Depending on the nature and complexity of the test, the cost of genetic testing can range from under \$100 to more than \$2,000.¹⁸ This, combined with the fact that there are currently 968,760 construction laborers employed in the U.S.,¹⁹ totals up to about \$96,876,000 to \$1,937,520,000 spent on genetic testing on all construction workers throughout the industry as a whole. Of course, there are many other factors to consider when determining the cost of genetic screening to construction companies, such as the cost of prescribing NSAIDs versus opioids must be considered. However, NSAIDs are widely-available drugs. Nonetheless, the multi-billion costs to the construction industry as a whole for affording genetic testing and providing medication to construction workers are a fair bargain to relieve the multi-hundred-billion losses of profit dealt by the perpetuation of the opioid abuse epidemic among construction workers.

Classifications of CYP2C9 genetic variants per allelic variant

The CYP2C9 gene produces the hepatic CYP2C9 enzyme that contributes to the metabolism of many drugs, including several NSAIDs (celecoxib, diclofenac, flurbiprofen, indomethacin, ibuprofen, lornoxicam, meloxicam, nabumetone, naproxen, piroxicam, and tenoxicam).⁶ The CYP2C9 gene is highly polymorphic, with over 61 alleles that confer either reduced or no enzymatic activity, including the normal enzymatic activity CYP2C9*1 wild-type allele.⁵ These are the most commonly reported alleles, and they are thus categorized into functional groups as follows: Normal function (e.g., CYP2C9*1), decreased function (e.g., CYP2C9*2, *5, *8, and *11), and no function (e.g., CYP2C9*3, *6, and *13). Allele function assignments have been made based on available in vitro and in vivo data, with consideration for their clinical actionability. Each allele's functional status is assigned an activity value ranging from 0 to 1 (e.g., 0 for no function, 0.5 for decreased, and 1.0 for normal function), which are summed to calculate the activity score (AS) for each genotype. An individual with the *1/*1 genotype tends to be a "normal metabolizer" of NSAIDs with an AS of 2. An individual with the *1/*2 genotype tends to be an "intermediate metabolizer with an AS of 1.5, while individuals with the *1/*3 or *2/*2 genotypes also tend to be "intermediate metabolizers", but with an AS of

1. Finally, individuals with the or *2/*3 *3/*3 genotypes tend to be “poor metabolizers”, with an AS of 0.5 and 0, respectively. There was no assignment for other CYP2C9 genetic variations due to a lack of strong clinical evidence.^{6,7,8,9}

Phenotype	Genotype	Activity Score (AS)
Normal metabolizer	CYP2C9 *1/*1	2
Intermediate metabolizer	CYP2C9 *1/*2	1.5
Intermediate metabolizer	CYP2C9 *1/*3 or *2/*2	1
Poor metabolizer	CYP2C9 *2/*3	0.5
Poor metabolizer	CYP2C9 *3/*3	0

Table 1. Association between CYP2C9 substrate metabolism phenotype, CYP2C9 genotype, and the corresponding activity score (AS).^{6,7,8,9}

Prescribing guidelines for celecoxib, flurbiprofen, ibuprofen, and lornoxicam

Based on these assignments (Table 1), there are certain recommendations for the prescription of celecoxib, flurbiprofen, ibuprofen, and lornoxicam. Those with normal metabolizer phenotypes should start therapy with the recommended starting dose. Following the prescribing information, the lowest effective dosage for the shortest duration should be prescribed, consistent with individual patient treatment goals. The same applies to those with intermediate metabolizer phenotypes, but there should be careful monitoring for adverse events, such as changes in blood pressure and kidney function, during the course of therapy. Those with poor metabolizer phenotypes should start therapy with 25–50% of the lowest recommended initial dose, which should be cautiously titrated upward to clinical effect or 25–50% of the maximum recommended dose. Following the prescribing information, the lowest effective dosage for the shortest duration should be prescribed, consistent with individual patient treatment goals. Upward dose titration should not occur until after steady-state is reached, which is at least 8 days for celecoxib and 5 days for ibuprofen, flurbiprofen, and lornoxicam after the first dose in poor metabolizers. Once again, there should be very careful monitoring for adverse events such

as blood pressure and kidney function during the course of therapy. Moreover, other therapies that involve drugs with low addictive potential that are not metabolized by the CYP2C9 gene or not significantly impacted by CYP2C9 genetic variants in vivo could be attempted or prescribed based on the prescribing information for those drugs.^{6,7,8,9}

Prescribing guidelines for meloxicam

There are certain recommendations for the prescription of meloxicam as well. Those with normal metabolizer phenotypes should start therapy with the recommended starting dose. Following the prescribing information, the lowest effective dosage for the shortest duration should be prescribed, consistent with individual patient treatment goals. The same applies to those with intermediate metabolizer phenotypes with an AS of 1.5, but there should still be monitoring for adverse events during the course of therapy. However, for those with intermediate metabolizer phenotypes with an AS of 1, therapy should be initiated with 50% of the lowest starting dose. The dose should be cautiously titrated upward to clinical effect or 50% of the maximum recommended dose. Following the meloxicam prescribing information, the lowest effective dosage for the shortest duration should be prescribed, consistent with individual patient treatment goals. Upward dose titration should not occur until after steady-state is reached, which is at least 7 days. There should be careful monitoring for adverse events, such as blood pressure and kidney function during the course of therapy.^{6,7,8,9} Moreover, those with poor metabolizer phenotypes should not be given meloxicam at all. Other therapies that involve drugs with low addictive potential that are not metabolized by the CYP2C9 gene or not significantly impacted by CYP2C9 genotypic variants in vivo should be attempted or prescribed based on the prescribing information for those drugs.^{6,7,8,9}

Prescribing guidelines for piroxicam and tenoxicam

There are certain recommendations for the prescription of piroxicam and tenoxicam as well. Those with normal metabolizer phenotypes should start therapy with the recommended starting dose. Following the prescribing information, the lowest effective dosage for the shortest duration should be prescribed, consistent with individual patient treatment goals. The same applies to those with intermediate metabolizer phenotypes with an AS of 1.5, but there should still be monitoring for adverse events during the course of therapy. However, those with intermediate metabolizer phenotypes with an AS of 1 and poor metabolizer phenotypes, should not be given either piroxicam or tenoxicam at all. Other therapies that involve drugs with low addictive potential that are not metabolized by the CYP2C9 gene or not significantly impacted by CYP2C9 genetic variants *in vivo* should be attempted or prescribed based on the prescribing information for those drugs.^{6,7,8,9}

Alternative therapies for poor metabolizers of CYP2C9 substrates

Acetaminophen

Although acetaminophen does not effectively reduce inflammation, it nevertheless remains a safe and effective analgesic. The prescription of acetaminophen, based on the appropriate prescribing guidelines, is a satisfactory alternative for those who need a safe analgesic but are also poor metabolizers of CYP2C9 substrates. In fact, people who are CYP2C9 poor metabolizers have an average response to acetaminophen.¹² Acetaminophen does not have any clinical annotations that discuss any clinically significant negative interactions with CYP2C9 genotype variants *in vivo*,¹¹ and also has no clinically significant negative interactions with the enzymes mainly responsible for its metabolism,¹² which are the CYP3A4, CYP2E1, and CYP1A2 enzymes, of which CYP2E1 is the most significant.¹⁰ Despite the fact that people with reduced CYP2E1 activity have reduced acetaminophen clearance and get a stronger response to this drug, and while several genetic variations in the CYP2E1 gene have been identified, pharmacogenetic testing for this enzyme is not used due to limited clinical evidence.^{12,29} Therefore, acetaminophen remains a generally safe alternative for poor metabolizers of CYP2C9 substrates.

Aspirin, ketorolac (short-term use), metamizole, naproxen, sulindac, and naproxen, etoricoxib, parecoxib, or valdecoxib

Aspirin, ketorolac (short-term use), diclofenac, sulindac, and naproxen, etoricoxib, parecoxib, or valdecoxib are other NSAIDs that could possibly be prescribed as a substitute for the aforementioned predominantly CYP2C9-metabolized NSAIDs. These drugs are not significantly metabolized by CYP2C9,^{6,7,8,9} and they appear to have no clinical annotations that discuss adverse events in individuals with certain genetic variants of the genes responsible for their metabolism. Therapies involving these drugs could be attempted or prescribed under the prescribing information for those drugs. To mitigate adverse drug reactions (ADRs) and their associated detriments to construction workers' health, therapies with these drugs should be considered as a secondary method due to the potential absence or misunderstandings of the pharmacogenomics of the metabolism of these drugs.

Aceclofenac, aspirin, diclofenac, indomethacin, lumiracoxib, metamizole, nabumetone, and naproxen

Aceclofenac, aspirin, diclofenac, indomethacin, lumiracoxib, metamizole, nabumetone, and naproxen are other NSAIDs that could possibly use as a substitute for the aforementioned predominantly CYP2C9-metabolized NSAIDs. The pharmacokinetics of aceclofenac, aspirin, diclofenac, indomethacin, lumiracoxib, metamizole, nabumetone, and naproxen are not significantly impacted by CYP2C9 genetic variants in vivo, and either in lieu with or rather as a result of insufficient evidence prevents recommendations to guide clinical use at present.^{6,7,8,9} Therapies involving these drugs could be attempted or prescribed under the prescribing information for those drugs. It is important to note that lumiracoxib has been withdrawn from the market in several countries, including the U.S. In order to mitigate adverse drug reactions (ADRs) and their associated detriments to construction workers' health, therapies with these drugs should be considered as a secondary method due to potential absence or misunderstandings of the pharmacogenomics of the metabolism of these drugs.

Possible side effects, contraindications, and complications of NSAIDs

NSAIDs are known to cause certain side effects, such as gastrointestinal ulcers and, in extreme cases, internal bleeding. When NSAIDs are used in the long-term, however, liver, kidney, and cardiovascular damage may be a consequence.²⁴ Moreover, the consumption of NSAIDs is generally not recommended for those with kidney, liver, heart, and blood clotting problems. Therefore, individuals who may need to use NSAIDs in the long-term as well as those who suffer from certain comorbidities that affect the kidneys, liver, heart, and blood circulation and clotting may also have to contend with these implications. This creates a considerable implication for the prescriptions of NSAIDs to construction workers because as of 2018, 29.8% of construction workers were obese, 20.5% had hypertension, and 10.4% had diabetes.²⁶ Obesity tends to account for about 65-75% of cases of primary hypertension.²⁷ NSAIDs should be prescribed in lower doses to construction workers with hypertension because NSAIDs hold the potential to have a vasoconstricting effect, which has the effect of further elevating blood pressure. Besides holding the potential to increase the detrimental symptoms of hypertension in construction workers, NSAIDs could increase the risk of stroke, heart attack, and other cardiovascular events in such individuals. In this case, acetaminophen might be a better alternative for pain management, albeit the lack of anti-inflammatory properties possessed by NSAIDs. Of course, genetic screening should still be performed to properly determine the appropriate initial dosage as well as the necessity and safety of upward dose titration. Moreover, as a significant number of construction workers suffer from MSDs and other musculoskeletal pain, NSAIDs should also hesitantly be prescribed if these individuals are also taking certain disease-modifying antirheumatic drugs (DMARDs). Concurrent use of low-dose methotrexate and nonsteroidal anti-inflammatory drugs (NSAIDs) may be associated with an increased risk of methotrexate toxicity.²⁸ Such a drug combination would only serve to decrease construction worker health, thus leading to reduced productivity and company losses.

Other considerations

The Convenience of Genetic Screening

The convenience of genetic screening may be in question, as current technology does not allow for instantaneous analysis of the entire genome. Waiting times for genetic screening results can take up to multiple weeks, which in the meantime, with the prescription of the usual opioids, may allow some construction workers to develop an opioid dependency, and soon addiction. Moreover, there are some ethical constraints with the genetic screening of construction workers, some individuals may object to genetic screening, creating a barrier to the prevention of opioid abuse.

Clinically-Relevant Haplotype

Studies have shown that more than 80% of individuals who carry the CYP2C9*2 allele also carry the CYP2C8*3 alleles in many populations.^{6,7,8,9,13} This could potentially have implications in vivo for drugs that are predominantly metabolized by both CYP2C8 and CYP2C9, such as diclofenac and ibuprofen. This could potentially result in more genetic screening for construction workers being required, which may add to the financial expense for construction companies.

Acetaminophen may not be a suitable alternative for CYP2C9 poor metabolizers

Although it may seem reasonable to bypass the CYP pathway to avoid the intricacies surrounding the different NSAID prescribing protocols per each variant phenotype, acetaminophen prescription may still threaten the opioid epidemic in the construction industry. Acetaminophen medications, such as the popular Tylenol®, are usually mixed with codeine,¹⁷ a type of opioid. This could leave the issue of opioid abuse unresolved because Cold Water Extraction (CWE) is a very easy and popular method used to tamper with opioid-containing drugs. CWE usually involves crushing and dissolving tablets in water and then using home utensils such as coffee filters to separate the codeine from the accompanying drug; in the case of Tylenol®, from acetaminophen.²¹ Therefore, the prescription of many acetaminophen-containing medications would not resolve the opioid abuse epidemic amongst construction workers, and may instead pose a threat to perpetuate the negative effects on worker health, and subsequent

company losses. Moreover, the combination of acetaminophen and codeine may cause serious or life-threatening breathing problems, especially during the first 24 to 72 hours of treatment and at any time the dose is increased.²⁰ This especially implicates construction workers because they have been shown to have statistically higher odds of contracting asthma, with 51.1% of construction workers in 2010 found to have been exposed to asthma-causing vapors, gases, dust, and fumes.^{22,23} The duality of acetaminophen and codeine in analgesic medications would only exacerbate the existing respiration issues, contributing to poor employee health, once again resulting in decreased productivity and company losses.

Summary

Given the non-addictive, superior anti-inflammatory, and analgesic nature of NSAIDs, construction companies should seek to promote NSAID therapy for pain relief and inflammation reduction while utilizing genetic screening for CYP2C9 genetic variants in their construction workers in order to personally tailor the course of pain relief and inflammation reduction. This will ultimately have the effect of reducing the opioid abuse epidemic in the construction industry, improving worker health and attendance, thus increasing productivity and company profits. Although there are other alternative drugs that do not utilize the CYP2C9 pathway as mentioned, namely acetaminophen, they lack the same anti-inflammatory nature that could possibly confer regaining of movement. Moreover, there are homemade methods used to tamper with over-the-counter acetaminophen-containing products to extract opioids such as codeine, which not only could propagate opioid abuse but could also confer acetaminophen hepatotoxicity, further posing a threat to construction workers' health and productivity. Meanwhile, other drugs lack significant pharmacogenomic investigations to safely guide clinical application. This is especially true for the alternative drugs that are NSAIDs, which are known to have the highly polymorphic CYP2C9 gene as an influence in their metabolic pathways. Additionally, the fact that there are certain comorbidities of concerning prevalence among the construction worker population may still implicate pain relief and inflammation despite personalized, CYP2C9 genotype-based tailoring of NSAID therapy. There may be other clinically relevant haplotypes and mutations in other genes involved in the metabolism of similar or alternative drugs held to serve as a potential substitute for NSAID therapy. Appropriate lifestyle changes will need to be taken into account, and further investigation may be required in regards to how genetic factors

can influence lifestyle. However, making the appropriate lifestyle changes is highly arbitrary, and poor lifestyle decisions could nullify or decrease the benefits of gene-guided NSAID therapy. As NSAIDs are unequivocally better at relieving inflammatory disorders than opioids, construction companies may choose to disregard genetic screening if any unreliability, convenience issues, or high costs do not deem genetic screening as cost-effective. Either way, more investigation is required into the cost-effectiveness of these features of personalized care. All in all, the opioid abuse epidemic among construction workers has been responsible for significant losses of revenue, incentivizing companies to seek personalized medicine that involves the more anti-inflammatory and less-addictive NSAIDs, and possibly genetic screening for the sake of improving worker health, attendance, and productivity, which all contribute to better profits for construction companies.

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