Psychological Well-being and Behavioral Interactions during the Coronavirus Pandemic

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Edited by

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KNOW BETTER, DO BETTER: THE ROLE OF EXPONENTIAL GROWTH UNDERSTANDING IN DECISION MAKING DURING THE COVID-19 PANDEMIC

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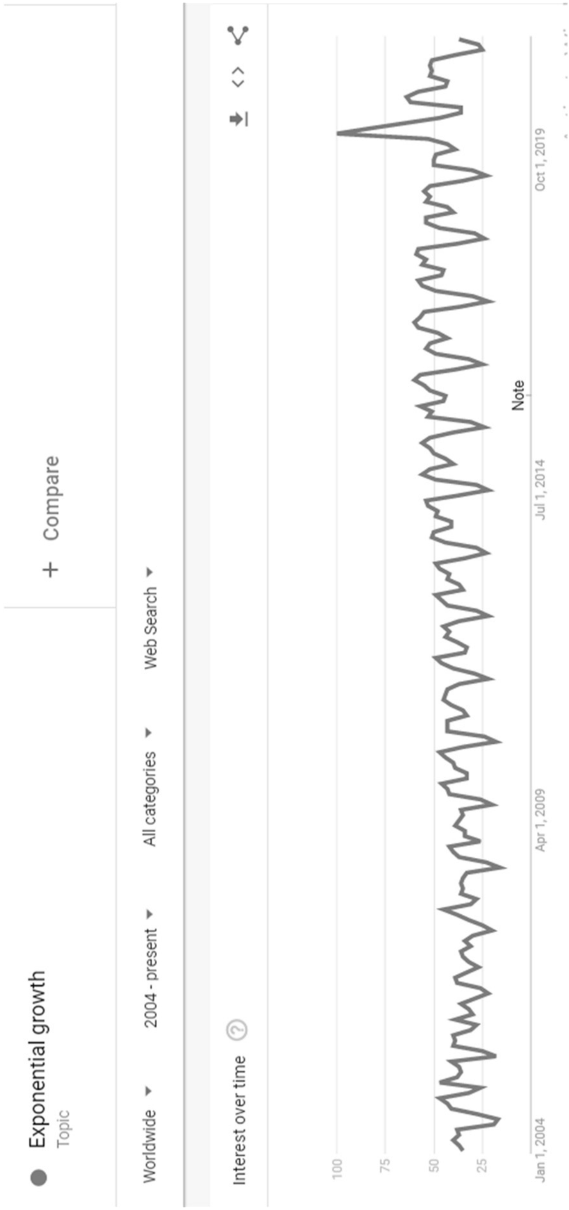
Abstract

People mistakenly use the term "exponential growth" to depict a fast-growing process rather than a specific mathematical concept with implications for the spread of the COVID-19 pandemic. Policies promulgated by the authorities during this period were misunderstood and resulted, in many cases, with shocking results worldwide. Biases associated with lack of complete understanding of the speed that the virus was spreading had an impact on the decision-making process. In particular, policy makers had to determine the proper balance between life-saving guidelines and economic costs associated with containment measures. In the future, governments must learn to manage such situations by better appreciating the impact of exponential growth to respond properly when a pandemic may reoccur.

What is Exponential Growth and Why Does it Matter?

Since the start of the global COVID-19 pandemic, the term "exponential growth" has increasingly appeared in the media (Heyd-Metzuyanim et al., 2021) and Google searches (Chart 1; Google Trends, 2021).

Chart 1: Use of the term “Exponential Growth” over Time.



Linear growth pertains to a consistent increase of a certain quantity over a period of time. In contrast, exponential growth refers to greater increases with passing time (Meadows et al.,1972). It can be said that linear processes grow by a certain number, whereas exponential processes grow by a certain percentage. Meadows et al. (1972) provide an example which highlights the difference between these two types of growth: Imagine you are given a sum of $100 with two options of increasing its worth: you may either deposit it in the bank and accumulate an annual interest of 7%, or you may place it in a jar and add the fixed amount of $7 each year. At the end of the first year, you would have $107 in either. However, at the end of the tenth year, the jar would contain $170 whereas the bank account would contain $196.72 due to ever-increasing interest rates. At the end of the twentieth year, the jar would contain $240 while the bank account would hold close to $400. This may not seem like a dramatic difference, but by the end of the fiftieth year, the bank account would contain 6.5 times more money than the jar – a difference of approximately $2,500! This is because the jar's sum would increase at a linear rate while the bank account's sum would increase at an exponential rate.

Exponential growth has sparked debate and served as a source of interest for centuries. A famous fable uses chess as an illustrative example to exemplify the vast incomprehensibility of exponential growth:

> Chess… was invented for the entertainment of a king who regarded it as training in the art of war. The king was so delighted with the game that he offered the inventor any reward he chose to name. The latter said he only wished to have the amount of corn resulting from placing one grain on the first square, two on the second, and so on, doubling the number for each successive square of the sixty-four. This sum, when calculated, showed a total number of grains expressed by no less than twenty figures, and it became apparent that all the corn in the world would not equal the amount desired. The king thereupon told the inventor that his acuteness in devising such a wish was even more admirable than his talent in inventing [chess] (Macdonell, 1898).

In the past forty years, research has shown that people underestimate exponential growth (Ebersbach & Wilkening, 2007; Wagenaar & Segaria, 1975). Given a hypothetical choice between receiving one million dollars or a stream of payments beginning with one penny and doubling each day, most people would likely choose the former. However, like the chessmaker's corn kernels or depositing $100 in the bank rather than the jar, the latter option is an example of exponential growth. Within 30 days, it would amount to a total of $5,368,709.12, making it the more worthwhile choice (Bitterly et al., 2020).

It is thus apparent that there is a fundamental difference between linear and exponential growth. However, many still mistakenly use the term "exponential growth" to depict a fast-growing process rather than a specific mathematical concept (Bitterly et al., 2020). The implication of this misuse is a widespread lack of understanding of the nature of exponential growth, especially in relation to some of the world's most pressing problems; human population growth, climate change, and infectious disease transmission all grow exponentially.

Human population growth poses a threat because of its exponential nature. There is not enough capacity for the expected population on earth and not enough resources at our disposal (Cohen, 1995). Moreover, our lack of understanding of the speed of population growth renders us unequipped in terms of infrastructure, sustainability, and development (Bergaglio, 2017). Similarly, environmental changes such as carbon dioxide concentration in the atmosphere occur at an exponential rate and must be responded to in kind (Hoffman et al., 2009; Kunreuther & Slovic, 2020). The same is true for the spread of infectious diseases such as the COVID-19 pandemic (Li et al., 2021).

Within scientific circles, the importance of exponential growth understanding has become evident. A book from the 1970s titled *The Limits to Growth* sought to "command critical attention and spark debate in all societies" by stressing the importance of understanding exponential growth and its ramifications (Meadows et al., 1972). Its authors warned against equating growth with progress and called their readers to action "to preserve the habitability of this planet for ourselves and our children" (Meadows et al., 1972). Unfortunately, their urgency is not shared by the wider public and human underestimation of exponential processes applies to all areas of exponential growth. This includes the COVID-19 pandemic. During the early phases of the pandemic, the number of infected individuals in the U.S. doubled every three days (Lurie et al., 2020). However, when studied, people consistently underestimated these figures (Banerjee et al., 2021; Hutzler et al., 2021; Lammers et al., 2020; Schonger & Sele, 2020; 2021).

There are various explanations of the underestimation of exponential growth. The most prominent theory, developed by two economists, is known as the Exponential Growth Bias. This theory posits that people tend to perceive exponential growth as a linear growth process (Stango & Zinman, 2009). This may be because many processes, such as aging and the passage of time, are linear. Therefore, we cannot easily perceive nonlinear processes and often mistake exponential growth for linear growth. It is because of the Exponential Growth Bias that during the COVID-19 pandemic many policies treated the spread of the disease as linear rather than exponential, leading to devastating results worldwide (Schippers & Rus, 2021).

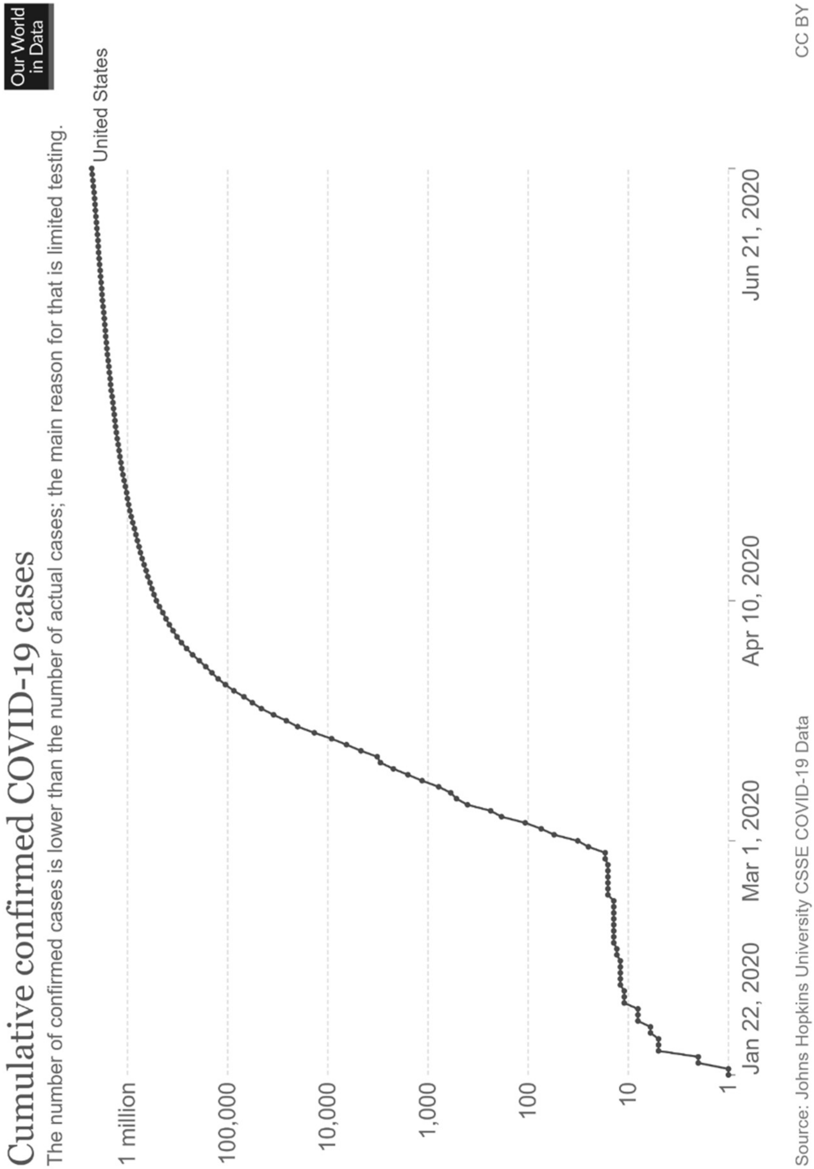
The Exponential Spread of COVID-19

Like other diseases, such as the 1918 influenza pandemic (Mills et al., 2004) or Ebola in West Africa (Pandey et al., 2014), COVID-19 spread at an exponential rate, at least during the initial phase of the pandemic in each country (Hsiang et al., 2020; Komarova et al., 2020; Lurie et al., 2020). The coronavirus is highly infectious and is transmitted either through direct contact (such as human-to-human transmission) or indirect contact (e.g., contaminated objects or airborne contagion; Lofti et al., 2020). COVID-19 belongs to the family of coronavirus which causes severe acute respiratory syndrome (SARS). There have been two previous coronavirus outbreaks this century: SARS (in 2002 and 2003) and Middle East respiratory syndrome (MERS; 2012-present). 2020).

The exponential trajectory of COVID-19 is evident in countries such as the U.S., Israel, and Iran. For example, according to the Centers for Disease Control and Prevention (CDC), the first confirmed case of COVID-19 in the U.S. was in Washington State on January 21, 2020 (Centers for Disease Control and Prevention [CDC], 2020). On March 21, 2020, just two months later, 26,025 cases were reported. And two months after that, on June 21, 2020, there were a staggering 2.28 million reported cases (Chart 2; Our World in Data).

The scope of the spread of COVID-19 is often referred to using the basic reproduction number, or simply, R_0. R_0 is defined as “the expected number of secondary cases produced by a single (typical) infection in a completely susceptible population” (Jones, 2007). In other words, R_0 is not a rate, but rather a dimensionless number. If R_0 is larger than 1, the infection will start spreading in the population. For example, if R_0 were to equal 2, as it did in the U.S. by March 2020, then each infected person would spread the virus to an additional two people. Thus, if on any given day two people have COVID-19 and each infects an additional two people, there would then be six people infected. This would continue until, just months later, the number of infected individuals would (and did) reach millions (Lammers et al., 2020). This illustrates the speed with which COVID-19 spanned the globe.

Chart 2: Cumulative Confirmed COVID-19 Cases.



Even in countries where the virus was contained more effectively than others, there was an initial exponential growth period (Komarova et al., 2020). Yet, following these beginning stages, some countries were more successful in containing the spread while others saw a more rapid rise in cases of infection. This suggests that the early stages of the pandemic were the most crucial in responding to COVID-19. Although there are many possible contributing factors causing a variance in the pandemic's growth curves in different countries, one such factor is the speed with which the virus was responded to. We suggest that this, in turn, was determined by the extent of understanding —or rather, misunderstanding— the nature of exponential growth. Therefore, we will examine multiple aspects of decision making during the pandemic and demonstrate how a better understanding of exponential growth led to more effective policy making and ultimately lower infection rates.

Decision Making during the COVID-19 Pandemic

When examining decision making during the pandemic, it is important to be aware that it is a multifaceted issue: there are many underlying factors which drive policy makers (Fischoff, 2020). One factor is policy makers' lack of understanding of exponential growth. To our detriment, the general public and world leaders alike failed to understand the exponential nature of the spread of the virus. As mentioned above, this may be due to the Exponential Growth Bias. For example, on March 26, 2020, then-U.S. President Donald Trump said, "I don't believe you need 40,000 or 30,000 ventilators. You know, you go into major hospitals. Sometimes they'll have two ventilators. Now, suddenly, they're saying, 'Can we order 30,000 ventilators?'" (CBS News, 2020). This quote demonstrates the prevalent disbelief and lack of understanding regarding exponential growth. Were the virus to grow in a linear fashion, a jump from two ventilators to tens of thousands would be inconceivable and unnecessary. However, due to the initial exponential nature of the virus (Hsiang et al., 2020; Komarova et al., 2020; Lurie et al., 2020), the number of infected individuals requiring ventilators and additional medical equipment reached high numbers very quickly, leading to the illusion that the need arose "all of a sudden".

Another bias which may account for poor decision making and delayed responses to the virus is known as the Human Optimism Bias. It refers to the phenomenon of underestimating one's susceptibility to various dangers. In the context of COVID-19, this bias likely accounted for the discrepancy between early warnings regarding the spread of the coronavirus and many countries' delayed reaction to it (Bottemanne et al., 2020). People underestimated the severity of the virus, their likelihood of contracting it, and how difficult the pandemic would be to contain (Bottemanne et al., 2020). By the time it became apparent that the coronavirus posed a real threat, it had reached large numbers which were nearly impossible to control.

In addition to these biases demonstrating lack of understanding, additional factors likely impacted the nature of decision-making during the pandemic. At the onset of COVID-19, amidst great uncertainty, policy makers were required to balance various interests while responding to the pandemic, the nature of which was not sufficiently understood (Schippers & Rus, 2021). In some countries such as the U.S. or Israel, the rise of the pandemic coincided with political change and turmoil. We will not delve into the political intricacies of decision making; however, it would be remiss not to at least superficially address this consideration. In countries where decision makers were in pursuit of political gain, their motivations were likely affected by those considerations in addition to public health and safety considerations.

Additionally, at the onset of COVID-19, policy makers had to determine the balance between taking life-saving measures and maintaining economic stability, all while facing uncertainties surrounding transmission methods and rates of the virus (Fischoff, 2020; Koffman et al., 2020; Schippers & Rus, 2021). One such method of assessment is known as Cost-Benefit Analysis. The theory of Cost-Benefit Analysis (CBA) is used in public policy to assess several possible outcomes and devise the optimal course of action (Pearce, 2016). Two major models of CBA were used at the onset of the coronavirus pandemic. The first, termed Value of Statistical Life (VSL), "represents aggregate demand for wide-spread, but individually very small, reductions in mortality risk." In other words, it measures the reductions people are willing to endure in their consumption of various goods and services in exchange for a small reduction in the probability of their death (Hammitt, 2020). It may, however, be argued that this model is not relevant for projecting coronavirus outcomes (Colmer, 2020), and that it does not sufficiently consider the effects of non-fatal cases (Kniesner & Sullivan, 2020).

The second CBA model is known as the quality-adjusted life-year model (QALY). It is a measure of the value of health outcomes and was developed as a method of combining length and quality of life into a single index number. It operates according to the following calculation: change in utility value induced by treatment is multiplied by the duration of the treatment effect. The result is the total number of QALYs gained (Briggs et al., 2021).

This metric, too, has its limitations and may be found unsuitable for specific contexts such as the COVID-19 pandemic (Pettitt et al., 2016).

Each of these models attempts to assess the cost of interventions and conclude if the measures taken are worthwhile or not, whether in economic or health terms. However, both were limited when applied to the COVID-19 pandemic, in that there was no guarantee that they would be relevant as long as the nature and impact of the virus were yet unknown (The Treasury of New Zealand, 2021). For this reason, CBA was not necessarily effective early in the pandemic, when taking effective measures was most crucial. The exponential spread of COVID-19 mandated that decisions be made even more quickly. Therefore, there was not enough time to gather adequate information to properly utilize the CBA models. However, their utility may be relevant regarding subsequent waves of the virus following a better understanding of its growth.

Notably, even after a CBA has been carried out regarding the spread of a disease such as COVID-19, policy makers must search for relevant information pertaining to the decisions which must be made. The CBAs are conducted by scientists, while policies are instated most often by politicians (AlKhaldi et al., 2021). Therefore, the gap between the two must be bridged: Policy makers must first access information from the scientific community. They must then accurately interpret the information (e.g., differentiate between linear and exponential growth) and grasp the urgency of the situation (AlKhaldi et al., 2021; Schippers & Rus, 2021). Finally, they must be able to act according to these updated conclusions (Schippers & Rus, 2021).

We believe that once decision makers understand the potential numbers of infection that may be reached, they will be urged to seek out the available scientific information and take action. The COVID-19 pandemic has demonstrated that when there is insufficient understanding of exponential growth and measures are not implemented quickly enough, there can be devastating results. Our hope is that policy makers can examine mistakes made during the pandemic and implement better strategies in the future, as elaborated below.

Containment Measures

In containing the virus, various interventions were taken to either mitigate or suppress it (Ferguson et al., 2019). Were no interventions to be taken, the virus would presumably have continued to spread rapidly and exponentially (Hsiang et al., 2020). Non-pharmaceutical interventions (NPIs), the efficacy of which has been proven, were put in place to mitigate the spread of COVID-19. These included restricting travel (Nouvellet et al., 2021; Xylogiannopoulos et al., 2021), contact tracing and self-isolation (Kucharski et al., 2020), enforcing mask wearing (Cheng et al., 2021; Howard et al., 2021), encouraging hand hygiene (El-Sokkary et al., 2021), implementing social distancing policies (Hsiang et al., 2020), and quarantine (Ashcroft et al., 2021; Nussbaumer-Streit et al., 2020; Xylogiannopoulos et al., 2021). Another method of mitigating the spread of COVID-19 has been vaccination (Tregoning et al., 2021). Interestingly, two studies emphasize that regarding vaccines, the speed with which the vaccines are distributed is more important than the vaccine's efficacy (Paltiel, Schwartz, Zheng & Walensky, 2021; Paltiel, Zheng & Schwartz, 2021).

In addition to mitigation strategies, suppression methods were put in place, the most common of which has been lockdown. However, the efficacy of this measure is questionable. While some researchers found that strict lockdowns effectively reduced cases of COVID-19 (Verma et al., 2020; Vinceti et al., 2020), others claim that although it is an effective measure, its adverse impacts on society, the economy, the humanitarian response system, and the environment, lead to a trade-off that is not worthwhile. Therefore, they conclude that it is better to implement and enforce other NPIs (Haug et al., 2020).

A systematic review of 34 studies on the effectiveness of NPIs discovered that the most effective measures have been school closure, followed by workplace closing, business and venue closing, and public event bans. Public information campaigns and mask wearing requirements were also effective in controlling the pandemic while being less disruptive for the population than other NPIs. No evidence was found regarding the effectiveness of public transport closure, testing, and contact tracing strategies, as well as quarantining or isolation of individuals (Mendez-Brito et al., 2021). Additionally, while the effectiveness of each measure has been studied alone, it is evident that a combination of strategies is better than isolated measures (Filonets et al., 2021; Giodarno et el., 2020; Haug, 2020; Hsiang et al., 2020; Mendez-Brito et al., 2021).

Importantly, early implementation of mitigation strategies was associated with higher effectiveness in reducing COVID-19 cases and deaths (Mendez-Brito et al., 2021; Nussbaumer-Streit et al., 2020), while delayed responses were associated with more cases of infection (Garcia-Basteiro et al., 2020; Royo, 2020). Research has even shown that, in terms of case evolution, countries in which the response to the virus was delayed by just three weeks after the first death were equated to those which did not take any measures of mitigating the virus at all (Xylogiannopoulos et al., 2021). This stresses the vital importance of immediate action to limit the exponential spread of infection.

Another study which used a statistical model to test the impact of policy and behaviour in the early stages of the pandemic supports this conclusion by assessing that requiring the use of face masks nationally in the U.S. "could have reduced the weekly growth rate of cases and deaths by more than 10 percentage points in late April [2020] and could have led to as much as 19 to 47 percent less deaths nationally by the end of May [2020], which roughly translates into 19 to 47 thousand saved lives" (Chernozhukov et al., 2021). The same study further found that stay-at-home orders decreased cases by 6 to 63 percent, and business closures by 17 to 78 percent (Chernozhukov et al., 2021).

Furthermore, countries that achieved higher success in containing the initial spread of COVID-19 were characterized by swift responses such as issuing advice to restrict travel to China, the epicentre of the coronavirus, several days before the first reported cases in their country (Xylogiannopoulos et al., 2021). Most of the countries with the highest success in mitigating the spread of COVID-19 border China. Xylogiannopoulos et al. (2021) speculate that this proximity led to prior experience with SARS and MERS which served as a precursor to their efficient response to COVID-19. Ultimately, countries that adequately understood exponential growth reacted quickly, and effectively mitigated the effects of the coronavirus.

Because controlling the spread of the virus is time-sensitive, government non-decisions are essentially likened to decisions. For example, the Trump administration did not immediately activate the Defense Production Act to produce and distribute required medical supplies across the U.S. This became a value-based choice driven by political pressure (Perez, 2020). Although it may be stated that making decisions during the early stages of COVID-19 was difficult due to high uncertainty regarding the nature of the disease, it cannot be claimed that this was an impossible task. Much knowledge has been accumulated from previous epidemics, such as the efficiency of NPIs, and several guidelines have been published on the topic of containing pandemics.

For instance, in April 2017, the CDC issued a document titled "Community Mitigation Guidelines to Prevent Pandemic Influenza" (Qualls et al., 2017). This is easily accessible on the CDC website and would have been relevant to the prevention of the coronavirus pandemic. Additionally, in September 2019, the World Health Organization (WHO) released a document detailing NPIs for combating epidemic and pandemic influenza. This document is also accessible on their website (World Health Organization, 2019). Similarly, the Ebola outbreak of 2016 served as preparation for containing COVID-19. Following the outbreak, the National Security Council (NSC) issued a 69-page playbook intended for the use of the U.S. federal government explaining how to effectively respond to a pandemic. Unfortunately, this playbook was ignored by the U.S. government during the spread of COVID-19 (Politico, 2020).

As of September 10, 2021, 41,561,156 people had been infected with the coronavirus and there were 674,547 reported deaths (Our World in Data). Had early interventions been implemented, it is likely these numbers would have been much lower. In turn, the likelihood of early interventions being implemented would have been higher had more people understood exponential growth. Such an understanding would lead to faster reactions, lower rates of infection, and a healthier society and economy.

This can already be rectified now. The Delta variant of COVID-19, first identified in India in December 2020, has recently caused a rise in infections worldwide (Rio et al., 2021). Simultaneously, coronavirus vaccines may have become less effective than initially thought to be, mandating additional responses (Baraniuk, 2021). For example, countries such as Germany and Israel have introduced a third vaccine as part of their efforts to maintain the mitigation of the virus's spread. It is paramount to implement the knowledge gained in the first waves of the COVID-19 pandemic when combating future incidents, and as demonstrated, to react quickly.

Conclusion

It has been proven that people lack an understanding of exponential growth. As such, we do not respond optimally to situations where we encounter exponential growth, including pandemics like COVID-19. Furthermore, like COVID-19, the most pressing of today's problems are exponential in nature. This mandates further education on the topic in order to secure the future of humanity. We must learn to manage such situations by increasing our understanding of exponential growth, acknowledging the urgency of adequate responses, implementing containment measures quickly and efficiently, and learning from the past. From the growing literature and in light of the COVID-19 pandemic, the importance of exponential growth literacy and understanding has become evident. We must further our understanding of exponential growth to effectively make decisions which have a global impact. Simply put, we must *know* better so we can *do* better.

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The Hidden Part of the Iceberg: The Impact of Social and Emotional Factors on the Links between Digital Divide and Online Learning in Times of Crisis

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Abstract

The COVID 19 crisis has been a sudden, unexpected, and globally encompassing crisis, which had led to a shut-down of all face-to-face teaching, making online learning the only route for continuing with academic studies. Digital resources have therefore become a critical element in learning, deepening the digital divide between students and impacting academic learning and achievements. However, while social-emotional factors have been acknowledged to play a role in learning, including in online learning, coping with the digital divide is still typically viewed as a technological problem, and the role emotions and social resources play in coping with the digital divide, in particular within a global crisis is relatively unexplored. This chapter presents research conducted among 375 undergraduate students from different colleges and universities in Israel during the first COVID outbreak. The research purpose was to examine the impact of emotions, social support and lecturer perception on the links between the digital divide and online learning. The findings indicated that online learning involves technological, social, and emotional aspects that interact in complex ways. Therefore, higher education institutes should consider those aspects and become engaged in finding ways to address them as part of online learning.

Introduction

Like most crises, the COVID 19 crisis has been Sudden and Unexpected, but it is also Globally Encompassing (SUGE), undermining systems' stability and disrupting systems (Shaluf & Said, 2003), higher education (HE) systems among them (Mastrodicasa, 2008). The crisis interfered with academic learning and teaching, with the mental and emotional wellbeing of students and their sense of safety (Akers, 2007). In particular, the complete shutdown of all face-to-face teaching, which has made online learning the only route for continuing with academic studies (Cornock, 2020), demanded the use of technology and, thus, has inflated and intensified the digital divide. While technical, economic and societal aspects of the digital divide have been widely studied, its emotional and social aspects have been scarcely investigated, particularly with regard to digital learning in times of crisis. However, there is a growing acknowledgement that learning (Brackett & Katulak, 2006), including online learning (Zembylas, 2008), is largely social and emotional in nature. Social and emotional factors may act as risk or protective factors. On the one hand, dealing with the digital divide in the context of the current crisis may bear emotional and social costs. On the other, positive emotions and the support of peers and faculty may help cope with the gap. It follows that the digital gap should be viewed as a multifaceted phenomenon that cannot be solved by simply increasing material access.

The present study sought to investigate the less studied role played by emotions and social interactions (portrayed by peer and faculty social support), in the links between students' digital divide and online learning in times of crisis.

Accordingly, the question that guided our research was: What, if any, are the impacts of emotions and social support of peers and lecturers on the relationships between the digital divide and online learning among students in HE institutions in times of crisis?

Shedding light on these aspects will allow HE institutions to better support students experiencing digital gaps and help them succeed in an increasingly technological and challenging environment.

Online Learning in Times of Crisis

Online learning is a term used to describe learning experiences accessed via electronic media, typically on the Internet (Horzum, 2017), in a synchronous (engaging both students and instructors at the same time, although in different locations) (Auster, 2016; Chauhan, 2017; Reid-Martinez & Grooms, 2018) or asynchronous (in which students and instructors jointly sustain learning activities, regardless of time and place) modes.

Online learning has been noted to offer connectivity, flexibility and a wide range of varied interactions (Anderson, 2008; Lebenicnik & Starcic, 2018; Moor et al., 2011; Rajab, 2018), to support forms of teaching and learning that are often more efficient, engaging and equitable than their offline alternatives (Selwyn, 2010). It has been argued that advanced technologies that accompany online learning may improve educational opportunities for learners (Moore et al., 2011). Online learning further allows to promote communication and sharing of information (Mackey et al., 2012), and to develop personal skills such as responsibility, accountability and time management (Conard & Donaldson, 2012; Kiekel, 2006; Ronen & Shonfeld, 2017).

However, not all students benefit from online learning to the same extent (Apana, 2008). In order to gain from its inherent benefits, online learning requires learners to own digital skills. It is here that the challenges posed by the Internet, new digital media, accelerated flow of information and new information and communication technologies (ICTs), on the one hand, and the digital divide on the other hand, have significant implications for education and learning and for the ability to benefit from online learning to the same extent (Apana, 2008). In times of crisis such as COVID (Mackey, Gilmore, Dabner, Breeze & Buckley, 2012; Rajab, 2018), with online learning the only possible route for academic learning (Cornock, 2020), concerns regarding accessibility increase.

Digital Divide

The term “digital divide” has been coined to describe the gaps in access to and in the use of the Internet between different segments of society. Until recently, the digital divide was most often conceptualized in binary terms: someone either had access to the Internet or did not (Hargittai, 2003). Accordingly, policymakers often expected the digital divide problem to be solved once a country’s Internet connectivity reached saturation (van Deursen & van Dijk, 2019).

However, other dimensions of the divide, such as the quality of digital networking infrastructure, autonomy of use, the presence of social support networks, experience, age, and online skills, have not been widely addressed (Eynon, 2009; Hargittai, 2003). This is true even though two of the main barriers to online learning were noted to be technological challenges (hardware and software) and the lack of technical skills (Muilenburga & Berge, 2005). Those are sometimes referred to as first order digital divide (concerning the actual access to ICT) and second-order digital divide (concerning the attitudes and skills associated with the actual use of ICT (Huang et al., 2015). New models of the digital divide concept now include a sequence of indicators spanning awareness, attitudes, physical access, skills and degree of usage (Deursen & van Dijk, 2015; Dray et al., 2011; van Deursen & van Dijk, 2019).

Studies of the digital divide have often been limited to developing countries that lack the technical and financial means to ensure access to information and communication technologies (ICTs) to all citizens. However, digital exclusion is found also in developed countries, and in particular among disadvantaged or less integrated communities within them. For instance, due to a range of language and cultural differences, new immigrants in first world countries often have less access to ICTs as compared with native-born citizens (Abascal et al., 2015). Additional variables that were found to account for digital exclusion included gender, age, level of education, level of income, race, ethnicity, being part of a minority group, rural versus urban populations and disabilities (Abascal et al., 2015; Deursen & van Dijk, 2015; Hargittai, 2003; Huang et al., 2015; van Deursen & van Dijk, 2019). Ultimately, the digital divide was noted to further exasperate current gaps between those who have the necessary resources in order to participate and thrive in society and those who do not (Eynon, 2009).

Digital inequality is especially challenging when it comes to education. Many students in developing countries, as well as in western countries, do not have access to the technologies that would enable them to participate in online learning, and therefore do not have an opportunity to be full participants in the digital age (Sims et al., 2008). This is particularly true when online learning has become the only option for learning.

While ways to overcome the digital divide have been the subject of ongoing research for several decades (e.g., Hargittai, 2003; van Deursen & van Dijk, 2019), those have typically been studied during routine times, or in times of crisis limited in time and area. For example, Open and Distance education have been noted to grant students equal learning opportunities and to promote democracy and citizenship during times of crisis, notwithstanding geographical, socio-economic, or other constraints (Bidarra & Fırat, 2020). More importantly, while the emotional and social aspects of learning are increasingly discussed, they have been scarcely studied in the context of the digital divide during a global pandemic.

Emotions and Online Learning

While scholars have called for more inquiry on the role of emotions in education, in recent years the relationships between emotions and learning, including in online settings (Artino, 2012; Zembylas, 2008), have been more widely acknowledged (McConnell, 2019). Thus, it is safe to assume that digital challenges involve emotions which may impact upon students' online learning, in particular in times of crisis.

While for decades education was mainly viewed as a cognitive process, educational settings are now recognized to be emotional places, in which students experience a wide range of emotions, both emotions concerning the educational process and emotions related to events outside it (Antilla et al., 2018; Brackett and Katulak, 2006; Hargreaves, 2001; Nias, 1996; Pekrun, 2014; Pekrun et al., 2017). According to Pekrun (2016), emotions related to learning may be grouped into four main domains: achievements; cognitive challenges; academic topics; and social interactions with teachers and peers. The pandemic and its health, economic and family implications can be related to the external (social) category of emotions, which may impact upon the educational process, too.

Online learning, in turn, was perceived until recently to be less emotional and more impersonal than face-to-face learning (Zembylas, 2008), in part because emotions associated with online learning are often more difficult to observe (Artino, 2012). Yet, a small body of available studies have demonstrated that emotions, both positive and negative, manifest themselves in online settings too (Zembylas, 2008), in a similar manner as face-to-face learning (Daniel & Stupnisky, 2012) and with similar impacts on learning, academic engagement, achievements (Artino, 2012) and motivation (Wlodkowski, 1999). Studies have also revealed that home computer usage was a determinant of students' self-perceived technology efficacy while shared school access was not. Emotional costs mediate the effects of home computer usage on technology efficacy (Huang et al., 2015), highlighting further the role played by emotions in online learning.

Such emotions have important impacts on learning, academic engagement, achievements (Artino, 2012) and motivation (Wlodkowski, 1999). It was found that for the majority of students, positive emotions, such as enjoyment from learning are beneficial while negative emotions such as anxiety, shame and boredom are detrimental (Pecrun, 2014).

These impacts of emotions on learning have been attributed to the guiding role of emotions in cognitive and motivational processes, actions and skills that promote learning (Zeidner, Matthews & Roberts., 2012), such as the availability of cognitive resources, problem-solving strategies and motivation to learn (McConnell, 2019), self-regulation, self-identity and well-being (Pekrun, 2014). Others pointed to the similarities in emotional responses between online learning and face-to-face learning in academic settings (Daniel & Stupnisky, 2012).

While the contributions of positive and negative emotions to learning and to academic achievements have both been explored, with the former being increasingly studied in recent years, the impact of negative emotions on learning has been more widely discussed. In online learning context, negative emotions, such as fear and anxiety were found to derive from a lack of familiarity with online learning technologies, from a sense of ambivalence towards it, from pressure to submit assignments on time, and from a sense of isolation and lack of face-to-face communications (Zembylas, 2008). Indeed, online learning has been noted to thrust students into an unfamiliar environment and to require high levels of personal adaptability and coping skills (Symeonides & Childs, 2015), which not everyone possesses, in particular when the digital divide is involved. For example, in one study, novice online learners demonstrated high levels of anxiety while learning to communicate online (Zembylas, 2008).

From a digital gap perspective, economically disadvantaged students with low-quality or no at-home access experienced higher anxiety towards using technology when compared to their better resourced peers. The term “emotional costs" was used in this context to describe the stress experienced by digitally disadvantaged youth who have to cope with digital requirements, and the negative emotions derived from a sense of falling behind their more advantaged peers, as well as from more material difficulties. These negative emotions in turn negatively impact upon academic outcomes as well as on skill building (Robinson, 2009; Huang, Robinson, Cotton, 2015; Huang, Cotton & Rikard, 2017).

However, most studies of emotions of online learning examined it during routine conditions such as in the case of the Open University online courses, as part of Distance Education programs or blended with other, offline, courses, (Zembylas, 2008), and not in in times of crisis, where the transition to online learning is full scale forced and unexpected.

By their very nature, crises and transitions are stressful and elicit negative emotions, the major ones being anxiety and stress (Jin & Fang,