Swipe, Click, and Hit the Brakes:

How Technology Affects Our Brain for the Worse

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Starting with stone tools and fire in the Paleolithic era, humanity has combined technique, knowledge, skill, and processes to produce items or services of value—or what we call *technology* today. Since then, technological milestones, such as the invention of the printing press and later the Industrial Revolution, have served as significant steps forward for mankind. However, while the utility and the positive impacts of technology are indisputable, if used incorrectly or with malintent, technology can be deleterious. Unfortunately, in this new generation of ubiquitous technology, the drawbacks and repercussions of technology are obscure and, in some cases, ambiguous.

The *bad* effects of consumer technology products (e.g. smartphones, social media apps, video platforms, etc) are especially nuanced. As a background, corporations and for-profit entities in the technology industry have long invested billions of dollars into human computer interaction ergonomics and user experience. And this is to no surprise: deliberately well-designed technology products means more people who use their product and longer the time these users spend on their product, which in turn brings in more advertiser revenue, more subscriptions fees, or ability to monetize alternative facets (e.g. user data). As a prime example, Instagram brought in $20 billion dollars in advertisement revenue alone in 2019 (Frier, 2020), as its monthly active users surged past 1 billion users. With profit so dependent on product use, companies compete with others to have users constantly and consistently use *their* product and, more importantly, are incentivized to design their products to be user-friendly and addictive. To illustrate this point, tech companies go as far as to use metrics that explicitly measure how frequently users use their product (e.g. monetizable daily active users, click-through rate, retention rate).

Conscientious efforts, such as the movement led by the Center for Humane Technology (Harris, 2020), have brought to light drawbacks of frequent use of consumer technology products on a sociological scale. Digital addiction, mental health, superficiality, and polarization are thought to be several of many harmful repercussions of technology use. Yet, institutional research on this topic is limited due to the constantly evolving landscape of technology products, the novelty of this issue, and the lack of general awareness of this issue. As such, long term effects of technology use on an individual's behavior and the brain remain largely unknown.

Though research is limited, preliminary findings suggest that constant technology usage and exposure to technology can have deleterious effects on behavior and the brain in the long term. These effects vary based on the stage of behavior, structural brain development, and functional brain development, with children's brain most susceptible to constant usage of technology. This paper explores the few empirical findings on how the negative effects of frequent technology use differ for adults and children—an already fully-matured brain versus a brain undergoing growth and change—and outlines future studies that more concretely identify ways that technology use changes the brain.

Research on how technology products effect children's brain is especially scarce. To date, no research has investigated the effects of being surrounded by technology ranging from infants to middle childhood. Luckily enough, for adolescent brains, some research exploring other trends, such as reading and media use, in adolescents reveal insights on how omnipresence and nonstop use of technology can change a developing brain. First, research by Twenge et al. (2018) found significant changes in adolescent reading behavior. For young adults, daily reading on some form of print decreased from 60% in 1970s to 12% today. In addition to this finding, meta-analysis conducted between 2000 and 2017 with over 170,000 subjects in 58 studies

indicated that young adults showed higher comprehension skills when reading text on print, rather than on digital screens (Delgado et al., 2018). Young adults who grew up with technology comprehend text better on print, but, alarmingly, these young adults are less likely to use thee more sophisticated cognitive processes required for reading print, as many have transitioned to reading just on screens.

Although scarce, few studies highlight the damaging effects of social media and other media engagements through technology for adolescents in terms of structural, functional brain development, and mental health, with longitudinal studies showing particular promise. Recent studies have shown that habitual and frequent use of mobile technology products is associated with reduced ability to delay gratification (Wilmer et al., 2016), but at the same time may increase one's ability to "flexibly switch between tasks" (Wilmer et al., 2017). Another promising study investigated the effect of media use on brain development of adolescents (Crone et al., 2018). The results demonstrated that because the neural systems that are associated with social reward and emotion-based processing, and regulation were underdeveloped, adolescents showed higher levels of sensitivity and reactiveness to acceptance and rejection on social media.

Most enlightening and useful insights, however, have come from longitudinal studies. Jun (2016), from longitudinal data of 1877 adolescent participants, found that severity of depressive symptoms increased with addictive use of mobile phones. Using the mobile phone addiction measurement from Korean Youth Panel Survey by Lee et al. (2002) and Korean Manual of Symptom Checklist (Kim et al., 1984), they monitored the response of 1877 participants for three years. Results indicated that, as mobile phone addiction and depressive symptoms increased consistently over time, the excessive phone use and depressive symptoms were bidirectional. Mobile phone addiction affected depressive symptoms and depressive symptoms

influenced mobile phone addiction. Although such longitudinal studies have proved to be insightful, as discussed later in this paper, there are challenges that have contributed to the lack of literature on the relationship.

Similarly, much of effects of technology to brain structure, brain function, and its related behavior for adults and the developed brain are unknown. Although many facets of technology's effect on cognition remain unexplored, foundational research in domains ranging from addiction to cognitive capacity thus far have elucidated alterations in the brain due to nonstop technology use, suggesting that patterns are beginning to emerge. He et al. (2017) identified anatomical difference in the brain for individuals addicted to Social Networking Sites (SNS). Using voxel based morphometry applied to structural Magnetic Resonance Imaging (MRI), He et al. scanned twenty SNS users of varying degrees of SNS addiction. Results indicated that SNS addiction is associated with "reduced grey matter volumes in the amygdala bilaterally", similar brain anatomy alterations to other addictions, such as substance and gambling.

Another area of preliminary research on technology's effect on cognition is how frequent smartphone usage can induce unwanted behaviors or negative changes in the brain. With figures constantly climbing, currently 81% of the US adults ("US smartphone ownership", 2020) and approximately 3.8 billion people worldwide ("Smartphone users worldwide", 2020) use smartphones. Many adults use their phone hourly and have become dependent on their smartphones. Such frequent use and dependence on smartphones can decrease cognitive capacity by the presence of phones. In two sets of experiments, Ward et al. (2017) investigated the effect of mere presence of smartphones on cognitive performance. In their first experiment, Ward et al. randomly assigned 538 undergraduate student participants into three different phone salience groups: phone on the desk, phone in the pocket/bag, or phone in another room. In these testing

conditions, the subjects took two measures of cognitive capacity exams, Automated Operation Span task and Raven's Standard Progressive Matrices. As seen in Figure A, results indicated that higher the smartphone salience (i.e. taking an exam with phone on a desk, facing up), available cognitive capacity decreases. In their second experiment, they added another layer by having the participants' phones turned *on* or *off* while separately performing cognitive capacity tasks, sustained attention tasks, and filling out a phone reliance assessment. A more sophisticated 3 (Phone Location: desk, pocket/bag, other room) × 2 (Phone Power: on, off) between-subjects design, this experiment ruled out any hypothesis that notification and unanswered messages may have been the cause for the decreased cognitive capacity. Ward et al. found that, again, decreasing the salience of the subject's phone increases cognitive capacity, but found no effect on sustained attention. Interestingly enough, finding no differences between phone-ON and phone-OFF groups, Ward et al. found decreases in cognitive performance to be the same for both groups, indicating that phone presence was the largest contributor in decreasing cognitive capacity. Despite institutional research being limited, preliminary research show a clear indication that dependency on constant use of technology is negatively altering human behavior.

On a rather interesting front, research conducted on how reading behavior is affected by technology use have yielded unique insights. Series of eye-movement research in the US and Germany have provided evidence that adult readers change their behavior drastically depending on the medium with which individuals read. Using digital screen devices, readers tend to skim, keyword-spot, and have a decreased level of sustained attention (Liu, 2012). This new mode for reading—"to skim to inform"—has raised concerns regarding the cascading effects of the changes in *how* we read: *how* we read alters *what* we read, which subsequently alters *what is written*, which ultimately changes *why we read* (Wolf, submitted). More importantly, research in

the detrimental change in reading behavior—one of myriad of dimensions in cognition—due to technology underscores the limited understanding of how frequent technology use has affected other aspects of cognition.

With limited research already elucidating some patterns of alterations in brain from constant use of technology, future research to better understand the repercussions of using technology is vital. Better understanding the effects of technology will enable us to understand how to best navigate the technology saturated world and how and when children should be introduced to such technology. And if future findings concretely indicate harmful effects of technology, we can implement solutions, guidelines or policies to mitigate any of those effects.

There are, however, unique problems with studies pertaining to this issue. First, the ubiquity of technology, especially everyday consumer technology products, makes it extremely challenging to develop empirical studies due to the difficulty of finding participants who do not use technology. Unfortunately, this limitation generally only allows quasi-experimental and correlational studies, from which conclusive evidence for causality cannot be drawn (Wilmer et al., 2017). Additionally, majority of studies exploring this field have used self-report questionnaires (Baumgartner et al., 2016). The nature of self-report questionnaires is such that they provide “only a narrow window” into the behaviors of interest and could be unreliable indicators of target behavior. Moreover, of note, due to the innovative and rapidly evolving nature of the technology landscape, technologies quickly become obsolete before any meaningful conclusions can be drawn. Most importantly, there is very limited evidence of longitudinal trends and long-term consequences of frequent technology usage (Wilmer, 2017). Due to the relative newness of most technology products, any long-term connection or affect between frequent technology use and cognition is inconclusive. However, despite these challenges, research—

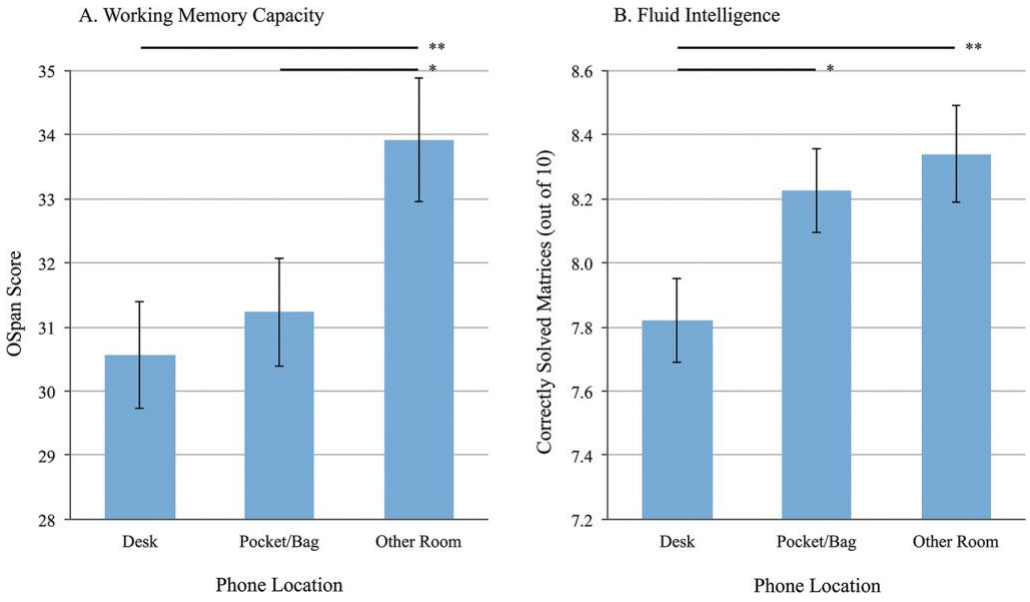
especially longitudinal research—will be crucial in elucidating question marks surrounding this issue.

Given the effectiveness and insightfulness of longitudinal studies, such as one conducted by Jun (2016) on bidirectionality of depressive symptoms and addictive phone use for adolescents, future direction and emerging research on technology use and cognition should be longitudinal. Because the effects of technology use for the developing brain and long-term effects remain unknown, future studies should look to amass conscientious parents whose newly born infants, whose technology use will be limited by the parent. The longitudinal study should probe inhibitory control, change in attentional networks, cognition, and mental health. With some already limiting or outright forbidding technology use for their households, these young subjects can be placed into different clusters by adjusting for variations in technology use depending on the households (i.e. *No Technology*, *Technology Once a Week,* or *Frequent Technology Use*). Once a year, the participants will be invited to the lab to complete a detailed survey regarding phone use and behavior, perform tasks measuring cognition, and mental health assessment. Longitudinal studies will be pivotal in understanding the detrimental effects of technology.

Conversations around how technology can surpass human capability is abundant; however, how technology can overwhelm human vulnerabilities is overlooked (“The Problem”, 2020). Regardless of whether technology products can be deemed pervasive or harmful, we will continue to use and depend on technology. The rising awareness have led to new insights on repercussions of technology, and as we understand more, whether to mitigate damage from technology will become clear. Until then, whether we need to hit the brakes remains unknown.

Figures

Figure A



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