The Mental and Physical Effects of High Smartphone Usage and the Design Measures that can be Taken to Mitigate Negative, Unintended Consequences

A Research Paper in STS 4600

Presented to the Faculty of the School of Engineering and Applied Sciences
Unviersity of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

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May 11, 2021

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Smartphones seem to have taken over the world around us. While they can be useful and effective tools for work, school, and socialization, they can have concerning effects on the user's wellbeing. Smartphone applications in particular have gotten increasingly popular over the past 10 years. Mobile app usage is currently at an all-time high and continues to grow rapidly. Application Intelligence Firm, App Annie, reports that time spent on mobile apps around the world hit a an all-time high of over 200 billion hours in April of last year (Kristianto, 2020). This uptick in usage over the past 10 years has created an extremely lucrative and attractive market. While most official numbers for last year have yet to be released, revenue from mobile apps was predicted to hit $581.9 billion in 2020 (App Annie, 2020). For comparison, Gartner research reports that worldwide revenue for all mobile applications totaled less than $7 billion in 2010 (Gartner, 2010). Companies are all fighting to make the best apps, and, in such a profitable industry, they are willing to do what it takes to ensure they are at the top. App Annie additionally reports that an average user spends 4 hours and 20 minutes per day on their smartphones, a record-breaking high. The world has never been more technologically dependent than it is today, and engineers need to evaluate the effects this dependence may be having on users. Understanding the effects this high smartphone and app usage has on users can allow engineers to determine solutions to help alleviate some of these unintended negative consequences in the future. This paper will investigate the physical and mental effects correlated with high smartphone usage and explore measures that can be taken to reduce these unintended consequences.

Responsible Innovation

It is the responsibility of engineers to evaluate the intended and unintended consequences of their ideas, creations, and designs. This obligation is the main idea behind the responsible

innovation framework. This framework was proposed by Jack Stilgoe and colleagues Richard Owen and Phil Macnaghten in 2013. Stilgoe and colleagues (2013, p.1570) define responsible innovation as "taking care of the future through collective stewardship of science and innovation in the present." The responsible innovation framework has four integrated dimensions as follows: anticipation, reflexivity, inclusion and responsiveness. These four dimensions stem from discussions, debates, and questions about what is truly important to consider as new technologies continue to emerge. Each of these categories bring in important considerations in the design process, including key concepts such as increased resilience and awareness and larger stakeholder groups to expand feedback and perspective.

Heather E. Douglas lays out a similar responsible innovation framework to Stilgoe in The Moral Responsibilities of Scientists (Tensions between Autonomy and Responsibility). She explains that scientists are morally responsible for the things they intend to bring about, as well as the side effects of their actions (Douglas, 2003). The terms "negligence" and "recklessness" are offered as the metrics for unintended consequences. Joel Feinberg defines negligence as creating an unreasonable risk to yourself or others and negligence as faultily creating such a risk (Feinberg, 1993). The key distinction between reckless and negligence is whether or not an individual has evaluated the situation and is aware of the potential risks involved. Recklessness involved awareness of unreasonable risk. This individual is knowingly creating a risky or dangerous situation but proceeds anyway. Interestingly enough, Douglas' paper acknowledges that there are times when reckless behavior is justified in its own way. However, Douglas explains that one can be held responsible for unintended consequences "both when things go the way one expects them to and when things go awry". Essentially, an individual can, and oftentimes should, be held responsible for their actions, independent of whether or not they may have been reckless. Douglas explains that the hardest part about negligence is determining what is considered to be a justifiable risk, and claims that the answer lies in what a reasonable person would have done.

Case Context

App Annie (2020) reports that an average user spends 4 hours and 20 minutes per day on their smartphones. With such high smartphone usage being reported, it is more important than ever to examine how this usage may be affecting users. Many games, apps, and websites aim to keep users on their platforms for extended periods of time to increase their revenue and exposure. However, these extended visits are taking their toll on users. Smartphone addiction is becoming more prevalent in the United States as the number of individuals who own smartphones continues to grow. According to a 2016 report from Common Sense Media, 50% of teens feel addicted to their mobile devices, and 59% of parents feel that their child is addicted (Common Sense Media, 2016). Additionally, according to a 2017 survey conducted by Deloitte, 70% of individuals who attempt to limit their smartphone use are unsuccessful (Richter, 2017). This prevalence begs the question of whether these developers and engineers are being reckless or negligent in their designs and creations. As Douglas (2003, p.66) describes, engineers must carefully consider the "possible impacts and potential implications of their work".

While mobile applications and smartphones are technical elements, this mobile addiction can have extremely large human and social impacts. Mobile addiction can have physical, mental, and academics effects. Beginning with the mental effects, a cross-sectional psychiatric study conducted in 2018 found that "addiction to smartphone usage is a common worldwide problem among adults" and that "the positive correlation between smartphone addiction and depression is alarming" (Alhassan, 2018). Additionally, stress, anxiety, and sleep deficit are also associated with internet and smartphone abuse.

In addition to these drastic mental health effects, the negative physical health effects are alarming. Perhaps the most notable physical consequence is a lack of physical movement. As online platforms aim to keep users engaged for as long as possible, users' physical movements are decreased which leads to an entire subset of physical consequences in itself. A study from the

National Center for Biotechnology Information found that “high frequency [cell phone] users were more likely than low frequency users to report forgoing opportunities for physical activity in order to use their cell phones for sedentary behaviors” (Lepp et. all, 2013). In addition, prolonged periods of screen time can lead to strain on the eyes. Nvision Centers reports that “studies have suggested the blue light from screens can damage retinal cells, leading to problems like age-related macular degeneration” (Nvision, 2020). Lastly, as smartphones continue to trend upwards in size, the design of certain apps and mobile interfaces are creating strain on the hands. Figure 2 depicts regions of a smartphone screen that are easily accessible to the hand versus those that are not, based on the position in which a user holds their phone.

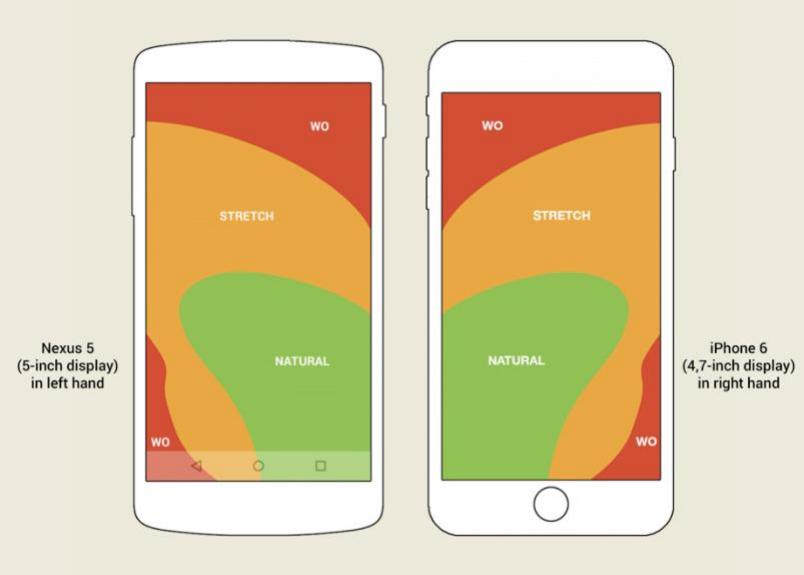

Figure 1. One-handed mobile interface zones (Savchenko, 2015)

The red regions marked in Figure 2 indicate “dead-zone” regions of the screen in which users have to severely stretch their thumbs. Steven Hoober began research on this topic in 2013 and found that the highest proportion of users used a one-handed method which results in the

interface zones shown in Figure 2 (Hoober, 2013). Aside from these stretches being inconvenient for users, this repeated thumb stretching can be damaging to the hand. Dr. Wyzykowski of Muir Orthopedic Specialists explains that a common smartphone related injury he sees is injury to the texting thumb, "which is a repetitive stress injury known as stenosing tenosynovitis" (Wyzykowski, 2018). Both the physical and mental health effects tend to be worsened with prolonged usage over an extended time. It is crucial that measures are put in place to help alleviate some of these effects. The two most important strategies to fighting them are to reduce smartphone usage by encouraging breaks and to design interfaces with these concerns in mind.

Some apps have begun to incorporate features that remind users to take breaks, but most apps, websites, and interfaces have no such features in place. When encouraging breaks, it is important to note that even small breaks can be beneficial. Additionally, when designing interfaces and placing high traffic icons and buttons, it is crucial for developers to be cognizant of screen zones. Doing so can help limit stain on the hand and prevent injury.

Research Design

The research question being evaluated is: *How does high mobile app and smartphone usage affect the physical and mental wellbeing of users, and what design measures can be taken to mitigate negative consequences?* More people today have smartphones than ever before. According to the PEW Research Center, 81% of Americans owned smartphones in 2019, a drastic increase from just 35% in 2011 (PRC, 2019). They additionally report that smartphone dependency has been trending upwards over time. With such widespread use, it is critical to evaluate the effects of prolonged use.

To address this research question, I have collected data by distributing surveys. The main goal of this approach was to determine how high mobile phone and app usage affects users and what measures may help minimize unintended consequences. Surveys offer advantages such as

low researcher bias, precise results, and relatively high representation. The surveys allow me to gather information on frequency of smartphone use, levels of smartphone dependency, any potential negative consequences, and other relevant data. To analyze the collected data, I primarily used procedural analysis, which has allowed me to analyze the quantitative data received from the surveys. Software such as Excel and Minitab have allowed me to take a deeper look at the survey responses and look for interactions, conditions, and subcategories that may have significance.

The survey is a 13-question snapshot into how much participants use their smartphones, how they spend time on their smartphones, and the negative side effects they may or may not experience. It was taken online via 96 participants. Data was collected on the participants' age bracket, and the breakdown is as follows: 91 participants aged 18-24, 1 participant aged 24-29, 2 participants aged 30-39, 0 participants aged 40-49, and 2 participants aged 50-59.

Results

The survey offered insights into participants' smartphone patterns and the results are significant in three distinct areas: how they use their phones, how much they use their phones, and how this use affects them. Overall findings indicated a strong dependence on smartphone devices and high reports of negative consequences.

When looking at the research question, one of the most significant findings pertains to the dependence participants feel towards their smartphones. 55% of participants reported being unable to go the day without using their smartphone. 28% of participants said they couldn't go a few hours without it. Only 5% of participants reported feeling no dependence on their smartphone. This dependence typically goes hand in hand with the negative consequences the users experience. 89% of participants said they experience negative consequences associated with smartphone use. Furthermore, 41% of participants reported that they feel addicted to their

smartphone. 20% of participants were unsure whether they were addicted to their smartphone, and 38% said they were not addicted to their smartphones.

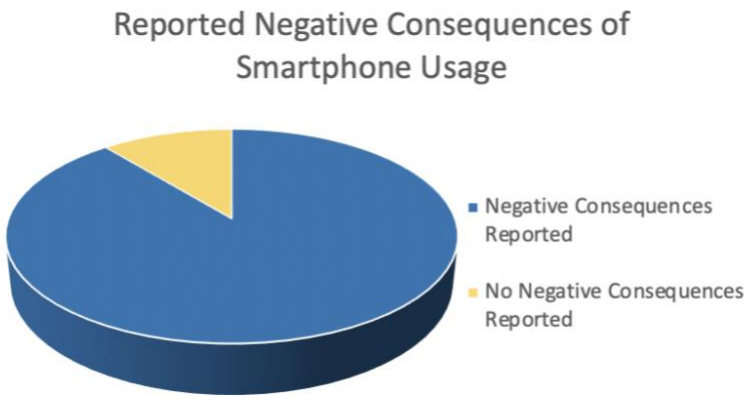

Figure 2. Participant Breakdown on Reporting of Negative Consequences (Peck, 2021)

The participants were asked to indicate what they use their smartphones for. The highest-yielding responses were “Contacting others via text” at 99%, “Social Media” at 97%, “Music or Podcast Playing” at 94%, “Email” at 92%, and “Contacting others via Phone or Video Chat” at 92%. The participants were additionally asked which service they spend the most time using on their smartphones. 62% of participants indicated that they spend the most time on social media. This was the highest reporting category with the next highest, “other media sources”, coming in at just 17%. The survey indicated that “other media sources” included categories like YouTube or TikTok. Interestingly, the highest contact-based service came in third with just 10% of participants indicating that they spend the majority of smartphone time contacting others via text.

To gauge temporal smartphone use, participants were asked to first estimate how many hours per day, on average, they spent on their phones. Then they were asked to use their phones settings to report the actual number of hours per day they spent on their phones on average. Only

32% participants were able to accurately gauge how many hours per day they spent on their phones to within a 2-hour time window. Meanwhile, 40% participants underestimated their average daily smartphone usage, and 23% participants overestimated their average daily smartphone usage. 4 participants were unable to determine their usage through their phone's settings.

Many smartphones have recently begun to add additional features to their settings to help users manage their screen time or reduce negative consequences associated with their use. 73% of participants reported having some form of measure in place to help limit phone usage or negative side effects of phone usage. 27% reported having no such measures in place. The most common measure reported was blue light reduction, which the public has become increasingly aware of in recent years. Interestingly enough, of the participants who reported smartphone addiction, only 33% had any of these measures in place to limit usage or the associated negative consequences.

Discussion

Looking back at the responsible innovation framework, a question arises of who specifically should be held responsible and accountable for reducing unintended consequences. It's an interesting dynamic since the goal of application developers, for example, is to create a successful and usable app, where success is typically measured by frequency of use. Can these developers be held responsible and charged with the idea of negligence or recklessness seeing as they *are* tasked with making a high-use application? An interesting perspective is that it may not be the responsibility of the game or app developer to reduce these unintended consequences, however we *can* shift the responsibility upwards to the broader OS level. Take Apple for instance. They don't face the same responsible innovation conflict faced by app developers, since their primary goal is not to hook users. Apple's goal is simply to make a product that is helpful and efficient, which does not necessarily require high frequency usage or dependence.

Consequently, a strong argument is made for the responsibility to be shifted up to a high-level to the general software and operating system companies at the top.

A limitation from the qualitative data is that the survey was far less likely to make its way to participants who do not own or possess a smartphone. Of the 96 participants, every single one reported owning a smartphone. The distribution process involved channels such as word of mouth, course email chains, and organizational communications. This, combined with incredibly limited in-person contact, made it difficult to reach larger groups of participants who were less similar to one another. Consequently, the sample size is not representative of the entire population. It was taken primarily by individuals that fall within the 18-24 age range. Most of these participants were college students who use technology in their day to day lives.

Another limitation is that order effects were not studied when creating the survey. The term "order effect" refers to "the well-documented phenomenon that different orders in which the questions (or response alternatives) are presented may influence respondents' answers in a more or less systematic fashion" (Schuman & Presser, 1981). The survey was created with a logical distribution in mind. That is, a distribution that would make sense to participants as they worked through it, however, it is possible that the ordering of the questions biased the participants in one way or another.

In the future, I would like to expand the participant pool to include a larger sample of participants in other age brackets. Particularly in the 40-49 and 50-59 brackets, it would be interesting to see how, if it all, the smartphone usage of these participants varies from that of college students. With just over 2% of the participants falling into those brackets, no real data is able to be evaluated. Additionally, if I were to expand on this study, I would like to conduct post-survey interviews on randomly selected participants. Doing so would allow me to dig deeper into a participant's thoughts with increased flexibility. The qualitative data from interviews would be helpful in determining next steps for the study.

When thinking about how this data relates to future engineering practices, it seems crucial to focus on the measures that can and should be implemented to reduce screen time and lower overall smartphone dependence. An interesting point is that the majority of participants who reported having some measures in place to reduce the negative consequences of smartphone usage had no measures in place to actually reduce time spent on their phones. Measures like the grayscale color scheme and blue light reduction certainly have physical benefits for users, but they aren't necessarily helpful in getting users off their phones. Time limits features can help users increase awareness of how much time they are truly spending on certain apps, however many users aren't aware that their phones have this feature. As discussed previously, even getting users off their phones for short breaks can have strong benefits.

Conclusion

As smartphones continue to increase in popularity and prevalence all over the world, it is more important than ever to evaluate how they are affecting users. As evident from the results of the survey data, users are feeling a strong dependence on their devices, and it is likely that these dependencies will only continue to strengthen. Alongside the dependence issues, the physical and mental effects of smartphone usage are worsening with prolonged use over time. It is crucial for designers and developers to fight these effects by finding ways to encourage reduced usage and to design interfaces with these concerns in mind.

The takeaways for future engineering work are two-fold: one, reducing overall screen time and dependence issues and two, reducing the negative consequences that come from usage in general. Focusing on design measures is a great start for designers and developers who are looking for ways to reduce these unintended, negative consequences. Elements we've already seen like blue light reduction and time limits features are strong building blocks for future endeavors in reducing negative consequences and limiting risk, but there is much more to be done to fundamentally change the ways in which we interact with our smartphones as a whole.

While designers and developers have an inherent responsibility to reduce the negative consequences of smartphone usage, it is imperative that users are in control of their own usage rather than relying on design measures that may eventually become helpful. Recognizing dependence issues is the first step in mitigating the negative effects that stem from smartphone addiction.

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Appendix A. List of Research Survey Questions Asked

Do you currently own or possess a smartphone?

- Yes
- No

Name (optional)

What age bracket do you fall into?

- 18-24
- 24-29
- 30-39
- 40-49
- 50-59
- 60+

How dependent do you feel on your smartphone?

- No dependence
- Can't go the day without it
- Can't go a few hours without it
- Can't go a few minutes without it
- Other

Check all that apply: What do you use your smartphone for?

- ❑ Social Media
- ❑ Watching TV/Movies
- ❑ Watching other media sources like Youtube or TikTok
- ❑ Games/Gaming
- ❑ Reading books or articles
- ❑ Contacting others via phone or video chat
- ❑ Contacting others via text
- ❑ Email
- ❑ School or work-related use
- ❑ Music or podcast playing
- ❑ Finance
- ❑ Exercise tracking
- ❑ Photo taking/editing
- ❑ Audio Recording
- ❑ GPS Navigation
- ❑ Taking or writing notes
- ❑ Researching or Googling
- ❑ Other

How to you spend the majority of time on your smartphone?

- Social Media
- Watching TV/Movies
- Watching other media sources like Youtube or TikTok
- Games/Gaming
- Reading books or articles
- Contacting others via phone or video chat
- Contacting others via text
- Email
- School or work-related use
- Music or podcast playing
- Finance
- Exercise tracking
- Photo taking/editing
- Audio Recording
- GPS Navigation
- Taking or writing notes
- Researching or Googling
- Other

Check all that apply: What negative mental consequences do you experience during smartphone use or as a result of smartphone use?

- ❑ Lack of sleep/ sleep issues
- ❑ Anxiety
- ❑ Loneliness
- ❑ Lack of concentration
- ❑ Stress
- ❑ Inability to communicate in person
- ❑ Decreases in overall wellbeing
- ❑ None of the above
- ❑ Other

Check all that apply: What negative physical consequences do you experience during smartphone use or as a result of smartphone use?

- ❑ Headache
- ❑ Eye strain
- ❑ Finger strain
- ❑ Neck strain
- ❑ Wrist strain
- ❑ None of the above
- ❑ Other

Would you say you experience negative consequences associated with smartphone usage?

- Yes
- No

If you believe you experience negative consequences associated with smartphone usage, how frequently would you say you experience these negative effects?

	1	2	3	4	5	
Very Rarely	○	○	○	○	○	Almost Always

Do you use any of the following methods to limit phone usage or negative side effects of phone usage?

- ❑ Time limits
- ❑ Greyscale
- ❑ Night mode/ Blue Light Reduction
- ❑ None of the above
- ❑ Other

How many hours per day, on average, would you ESTIMATE that you spend on your smartphone?

- ○ 0-1
- ○ 1-2
- ○ 2-3
- ○ 3-4
- ○ 4-5
- ○ 5-6
- ○ 6-7
- ○ 7-8
- ○ 8-9
- ○ 9-10
- ○ 10-11
- ○ 11-12
- ○ 12-13
- ○ 13+

How many hours per day, on average, do you ACTUALLY spend on your smartphone according to your phone's settings?

*Additional Instruction provided for participants: Most smartphones have features in their settings that report exactly how many hours per day you spend on your smartphone. Use this feature to report how many hours per day you spend on your phone.

- ○ 0-1
- ○ 1-2
- ○ 2-3
- ○ 3-4

- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- 10-11
- 11-12
- 12-13
- 13+
- Unable to determine from smartphone

Do you feel addicted to your smartphone?

- Yes
- No
- Maybe

*Space was provided at the end of the survey for participants to offer additional feedback, concerns, or questions.