Spring 2020

The Effect of Smartphone Separation and Dependence on Selective Attention

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Senior Project Submitted to

The Division of Science, Mathematics, and Computing

of Bard College

By Immanuel Zion

Annandale On Hudson, New York

May 2020

Acknowledgments

I want to thank my advisor Tom, for all of his help throughout the senior project process, especially when I needed help with R studio and setting up E-prime software before data collection. I also want to thank my parents for supporting and motivating me throughout this difficult time.

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Abstract

The current study investigated the effect of smartphone dependence and subsequent smartphone separation on selective attention. Performance on selective attention tasks was operationalized as response time and accuracy on two versions of the stroop response inhibition task. Smartphone dependency was operationalized as a score which exceeds the cutoff on the Smartphone Addiction Scale Revised edition (SAS-R). To create smartphone separation students were asked to place their smartphone in a provided basket during the experiment. It was hypothesised that students who are deemed smartphone dependent and then separated from their smartphones would perform worse across all blocks of the stroop task compared to those who do meet the cutoff score for smartphone dependency. Across standard stroop trials in block 1 and block 2 a congruency effect was found such that reaction time was significantly slower for incongruent word/color pairs then congruent word color pairs. However no effect of smartphone dependency was found across all blocks such that smartphone dependent individuals did not perform significantly worse compared to non dependent individuals.

Introduction

In the recent decade the emergence of smartphones and electronic devices has allowed for rapid and immediate relay of information from person to person. Smartphones and mobile devices occupy a significant role in the majority of people's lives. Over 86% of adults ages 20-24 report owning a smartphone whereas 91% of adults aged 18-19 report owning one (Pearson, 2015). With access to information and social media content, smartphones provide immediate and long term access to the digital world. However, with the average consumer spending considerable hours per day on social media, the question emerges (as) to the degree that constant smartphone usage, media consumption, and electronic device usage negatively impact attention. Current research suggests that habitual and instantaneous access to the digital world through mobile devices likely impacts attention, focus, and cognition in negative ways.

Technology Use in the Context of Addiction

An addiction is defined as a psychological or physiological need for a habit forming substance or object. Upon separation from that habit forming substance, the dependent individual often feels cravings, anxiety, and depending on the substance, physiological withdrawal symptoms. In accordance with the DSM V (diagnostic and statistical manual for mental disorders) addictive disorders fall into two broad categories: substance related addictive disorders and non substance related disorders, which include gambling disorders, and internet gaming disorder (American Psychiatric Association, 2013). Internet gaming disorder is defined as repeated playing of video games which can negatively impact one's emotional well being, ability to maintain relationships, career, and education. Research suggests that excessive video game use can have negative consequences on psychological and social well being. A 2018 study investigating disordered

video game use in adolescents found that students (ages 12-15) with gaming disorder, showed significantly worse academic performance along with lowered perceived social competence and life satisfaction (Eijnden, Koning, Doornwaard, Gurp & Bogt, 2018). Some research is also present on the relationship between internet gaming disorder and selective attention. In 2017, Kuss, Pontes, & Griffiths (2017) conducted a systematic literature review examining neurobiological correlates in internet gaming disorder. Analyzing the results from 27 studies, utilizing FMRI, EEG and other brain imaging techniques, it was found that compared to controls, gaming addicts showed worse performance on tasks of working memory, response inhibition, and emotional regulation, suggesting that internet gaming disorder negatively impacts both well being and cognitive functions (Kuss et al., 2017). Regarding smartphone dependency, given then smartphone use involves constant interaction with mobile devices it might be logical to assume that smartphone dependency might have similar negative consequences on attention.

Effects of Mobile Device Use on Attention and Cognition

Attention can be defined as a cognitive and behavioral process involving selectively concentrating on a stimulus. Attention can then be divided into two key areas: focused attention and divided attention. Focused attention can be defined as the capacity to attend diligently to a singular source of information while ignoring other incoming stimuli, whereas divided attention refers to the capacity to attend to multiple stimuli simultaneously (Wen, Yamashita, & Asama 2016). There have been a number of studies illustrating the negative effects of electronic device usage and media consumption on cognitive performance particularly in individuals who use several media mediums at once. These individuals are known as multitaskers. Baumgartner, Weeda & Huizinga (2014) found that media multitaskers reported issues with executive

functions, and Ralph, Thomson, Seli, Carriere, & Smilek (2013) found that frequent media multitaskers reported increased levels of attentional issues. Further, Ophir, Nass & Wagner (2009) found that frequent media multitaskers perform worse in tasks that require task switching. Since task switching refers to the ability to consciously shift between one task to another, Ophir et al. (2009) posited that lowered performance on task switching was due to an inability for multitaskers to filter out and inhibit incoming stimuli suggesting that media multitasking may negatively impact executive functioning ability.

There are a variety of ways in which attention can be diverted or lost. Mechanisms by which attention is diverted are conventionally known as distractors. Typically distractors come in two forms: endogeneous distractors, where one's own thoughts and drives alert attention and exogenous distractors where an external environmental cue alters attention (Wilmer, Sherman & Chein 2017). In terms of distractors, as it relates to smartphone usage, an alert appearing on one's phone is an example of exogenous distractor, where the notification prompts the individual to check their phone (thereby) creating an interruption in attention. The relevance of exogenous distractors as it relates to smartphone usage is present in the current literature. Stothart, Mitchum, & Yehnert. (2015) found that simply hearing the sound of a smartphone notification significantly affected performance on a selective attention based task in an order of magnitude similar to that of active phone usage. In terms of endogenous distractors, individuals who are prompted by one's own internal thoughts and understanding can come from looking at them in relation to immediate gratification. In other words, when looking at one's smartphone one might feel compelled to check social media, texts or messaging services as a means to seek immediate gratification. Logically then, delays in gratification may lead to further distraction since the

individual's compulsion to check the phone further commands and occupies their attention. Katz, Blumler & Gurevitch (1973) proposed a theory on emotional gratification suggesting that compulsions for technology use could be defined as a product of psychological factors that motivate media consumption and gratification as a perceived fulfillment of those compulsions. Several studies have attempted to investigate the impact of media consumption and technology use on delay gratification, delay gratification being defined as a process in which an individual attempts to control impulses and temptations. Wilmer & Chein (2016) found that increased usage of mobile devices was negatively correlated with delay gratification. Additionally Sanbonmatusu, Strater, Medieros-Ward, & Watson (2013) found that frequent media multitaskers reported heightened levels of sensation seeking, impulsivity and poorer working memory performance compared to controls.

The effects of increased media consumption on increased impulsivity along with a decreased ability to delay gratification is not just limited to frequent multitaskers. Hadar, Eliraz, Lazarovits, Alyagon, & Zangen (2015) found that in smartphone naive participants (i.e. participants who currently or have not previously used a smartphone) showed decreased ability to delay gratification as well as decreased information processing (Hadar et al., 2015). This finding suggests that issues of delay gratification involving smartphone use are not just limited to chronic smartphone users but also to individuals who have never used a smartphone.

Effect of Mobile Technology Use on Memory Function

Smartphones and mobile devices can provide unlimited access to information that allow one to then access facts and data with a simple Google search. However with such easy access to information it is likely that an over reliance on smartphones for information gathering likely

impacts memory capacity and the ability to recall information. Interest in the relationship between memory function and mobile device use has been prevalent in the literature. Sparrow, Liu, & Wegner (2015) investigated the impact of technology use on long term memory recall. Sparrow et al. (2011) found that when people assume to have access to information (at any time) in the future they show lower rates of recall but do recall where the information can be accessed, a finding referred to as the Google effect (Sparrow et al., 2011). During the procedure the experimenters had participants learn new trivia facts and then type those facts into a computer. Half the participants were told the computer would store the information and the other half were told that the information would be erased shortly. As a result, participants who thought they would have future access to information on the computer recalled significantly less facts than those who were told the information would be erased. This finding illustrates the role that technology and electronic devices have as potentially serving as external memories of which information that is quickly taken in is also quickly forgotten.

In relation to smartphone use, several studies emerged illustrating the effect of smartphone use on short term memory function. Research has also investigated the impact of mobile navigation systems/GPS on spatial memory. Burnett & Lee (2005) found that usage of mobile navigation systems impaired spatial memory as well as cognitive map building; the process by which significant spatial landmarks and locations are represented visually in the mind). Additionally Boari, Fraser, & Cater (2012) found that individuals who perform mental rotation during navigation far outperform those who rely on navigation software that performs an automated mental rotation task. This finding suggests that chronic smartphone users might show impaired performance not just on spatial memory but tasks that require spatial reasoning.

Several studies have also captured the impact of media usage on working memory capacity. Specifically Uncapher, Thieu, & Wagner, (2015) found that frequent media multitaskers showed worse working memory capacity accompanied by increased impulsivity and limited attentional control.

Effects of Smartphone Separation and Dependence on Cognition and Attention.

The majority of the studies referenced thus far have focused on the effect of smartphone usage on memory, delayed gratification, and cognition. However recent but limited research has gone into investigating the effects of smartphone separation and dependence on attentional performance.Smartphone separation can be defined as the act of distancing oneself from one's smartphone. One may physically separate themselves from their smartphone (physically being out of contact) or indirectly separate from a smartphone. An example of indirect separation can include silencing one's phone or muting all notifications. Smartphone dependency can be defined as smartphone overuse which can create problems for the smartphone user. Individuals who experience smartphone dependency may experience difficulty stopping the use of texting, social media or any other task involving a smartphone. In 2013 Kwon and colleagues (2013) developed a revised version on a Smartphone Addiction Scale consisting of 10 questions pertaining to smartphone habits and overuse. Questions include: “I have difficulty concentrating due to my smartphone” and “ I will never give up my smartphone despite how it negatively affects me.” For each question, the participant responds with a rating from 1-6 with 1 defined as strongly disagreeing and 6 defined as strongly agreeing. The maximum score on the scale is a 60. Kwon et al. (2013) established a dependence cut off score of 33/60 suggesting that an individual is likely smartphone dependent at or above this cutoff score.

A few studies have investigated the effects of smartphone dependency and subsequent separation on attention and cognition. Hartano and Yang (2016) investigated the effect of smartphone separation on executive functioning. Executive functions are sets of key mental processes involved in self control, planning, and task shifting (Yang et al., 2016). There are several components to executive functions, partriculary, response control, working memory, task switching, and mental flexibility. Yang et al. (2016) set out to examine the effects of smartphone separation on executive function performance specifically in task switching and inhibitory control (Experiment 1) and working memory (Experiment 2). The experimenters utilized the stroop task as one of their measures of inhibitory control and in a complex rotation task for working memory. Yang et al. 2016) found that participants who were separated from their smartphones performed significantly worse on the nonverbal stroop task and the mental rotation tasks compared to controls thereby suggesting a negative impact of smartphone separation on attention and cognitive performance.

In terms of smartphone dependence, Lee, Cho, Kim, & Nih (2015) investigated whether the degree in which one is addicted to their smartphone impacts their ability to achieve a flow state. A flow state is defined as a heightened mental state in which an individual's experiences hyperfocus and reports being fully involved in a task. They also found that increased levels of dependence on one’s smartphone was negatively correlated with flow state, suggesting that increased smartphone use and dependence might negatively affect focus and the ability to stay on task.

Based on the current literature, there seems to be a negative relationship between smartphone usage and difficulties with emotional regulation, attentional control and memory

function. The literature suggests that both active usage and the mere presence of a smartphone can disrupt tasks that require focused attention and cause difficulty with tasks that are cognitively demanding. Although there is a clear negative relationship between excessive smartphone use and cognitive performance, the majority of the current data is based on self report and based on correlational research. With the exception of a handful of studies, there are few empirical studies investigating the impact of smartphone dependence and subsequent separation on cognitive functioning, particularly selective attention. Among those studies Yang et al. (2016) found that participants who were separated from their smartphones performed significantly worse on tests of executive function including nonverbal stroop and complex rotation tasks. However Yang et al. (2016) did not find a distinct impact of smartphone dependence on lower performance with executive function.

The purpose of the present study is to expand upon the current literature and the findings of Yang et al. (2016) and investigate the role of smartphone dependency and subsequent separation on selective attention performance. As in previous studies, participants will be separated from their smartphones. However, to further investigate the degree to which smartphone dependence impacts the relationship between smartphone separation and attentional performance, this study will feature two new tasks in which the participant first interacts with their smartphones followed by a test of selective attention. Participants will then be separated from their smartphones and evaluated for smartphone dependency. This will be followed by a completion of a standard stroop task. Following the completion of the standard stroop task, the first new task will be implemented. Participants will be given back their smartphones and asked to complete a short trivia questionnaire consisting of general knowledge and vocabulary style

questions. Participants will be allowed to use their smartphone to google difficult questions. Participants will then complete another block of standard stroop. The purpose of this task is to illustrate in real time the process of active smartphone usage followed by abrupt smartphone separation on stroop performance. Following this, the second novel task will be implemented where participants complete a smartphone specific stroop task consisting of a combination of neutral items (House, Dog, Forest, Key) and smartphone related items (Message, Text, App, Notification) and where the participants are asked to name the color of the stimulus word while ignoring the words meaning. The purpose of this task is to assess the impact of smartphone related item types on attentional performance in participants who are seperated and dependent on their smartphones. Given that smartphone dependency in large part involves constant and perhaps obsessive thinking about one's smartphone with corresponding anxiety regarding one's smartphone, it is assumed that providing the participants with item types that cue smartphone related usage will trigger a participants dependence on their smartphone. Thereafter, a significant amount of attentional resources are utilized resulting in a demonstrably worse performance on the task itself. No test like this seems to be present in the current literature.

H1: Given the current literature, it is hypothesised that there will be a main effect of dependency. Participants who meet or exceed the cutoff score for smartphone dependence will perform significantly worse both in terms of accuracy and reaction time on the standard stroop tasks compared to participants who do not meet the cutoff score for smartphone dependence.

H2: It is hypothesised that there will be a main effect of smartphone separation. Participants who are separated from their smartphones will perform worse (in terms of accuracy and reaction time) on both the standard and smartphone specific stroop tasks.

H3: It will be hypothesised that there will be an interaction between smartphone dependency and performance on the smartphone specific stroop task, whereby participants who do meet the cutoff score for smartphone dependency and are separated from their smartphones will perform significantly worse on the smartphone specific stroop task, specifically on the smartphone specific items (Notification, Message, Text, App) (in terms of accuracy and reaction time) compared to students who do meet the criteria for smartphone dependence.

Method

Participants

22 participants were recruited from the undergraduate population at Bard College. The initial goal for the number of participants was 40 participants, however due to abrupt shutdown of Bard College campus due to the corona virus outbreak, data from only 20 participants was collected. The length of the experiment was approximately 30 minutes. Participants were recruited with flyers posted on campus with specific information regarding the date and time of the experiment, and also with a sign up on Sona Systems via their Bard email address. Upon arriving in the experiment room participants completed a demographic questionnaire consisting of questions pertaining to age, current date, gender identity, fluent languages spoken and the use of glasses or a hearing aid. Participants were also asked to complete a consent form stating the participants rights and choice to leave the study at any time. The study began upon completion of the consent form and demographic questionnaire.

Experimental Design

For this experiment a three way mixed design with Dependency (dependent/not dependent) as a between-subjects factor and Condition (congruent, incongruent) and Block (block 1/block 2) as a within-subjects factors to see the relationship between performance on selective attention and the influence of being smartphone dependent and separated from one's smartphone. Selective attention performance was operationalized as performance on two versions of the stroop task: a standard stroop task and phone specific stroop task (see materials and procedures below). Smartphone dependency was operationalized as meeting or exceeding the cutoff score on the Smartphone Addiction Scale Revised (SAS -R). Smartphone separation was operationalized as asking the participant to place his or her phone into a provided basket prior to beginning the stroop task(s).

Materials and Procedure

Smartphone Dependency Scale Revised

During the study, participants were asked to complete a shortened version of the smartphone addiction scale. The scale consists of 10 questions pertaining to smartphone usage and habits including questions such as: " I use my smartphone longer than I intend to" and " I cannot stand not having my smartphone". Participants responded to the questions on a 6 point likert scale. From 1 being "strongly disagree" to 6 being "strongly agree." Following completion of the questionnaire, rating scores on each question were added up to form a scaled score (0-60). The designated cutoff score for smartphone dependency by the scale was 33/60 (see appendix for full list of questions).

Standard Stroop Task

Participants were asked to complete a standard Stroop task in which participants were shown a word (Blue, Green, Red, Yellow) and were asked to name the color of the word while ignoring the word's meaning. For example, if the word blue is presented in blue ink the participant would say blue. If the word blue is presented in red ink the participant would say red. The stroop task was generated and run using E-prime. While completing the tasks, participants named the words color by speaking into a provided microphone. Response data was recorded both for reaction time (in milliseconds) and accuracy.

Trivia Questionnaire

Upon completion of the first block of the standard stroop task, participants were asked to complete a 10 question trivia questionnaire consisting of various general knowledge and vocabulary questions starting off as generally easy then progressively increasing in difficulty. Questions included items such as: “what is the capital of New York” and “define dilatory”. Participants were informed that they can use their smartphones while completing the task. Questions for the trivia questionnaire were created using an online generator with specific subjects of general knowledge and vocabulary (see appendix for full list of questions).

Stroop Task With Smartphone Specific Words

In addition to a standard stroop task, participants completed a smartphone specific stroop task containing a combination of neutral words and smartphone related words. Neutral words included words such as House, Forest, Key and Dog and smartphone related words included those such as Message, Notification, Text, and App. Words pertaining to smartphones were compiled using a random word generator within the subject of smartphone. During the task participants were again asked to name the color of the presented word while ignoring the word's

meaning. For example if participants saw the word Text in green ink they would say green. The smartphone specific stroop tasks was also generated using E-prime and participants vocalized their responses into a provided microphone. Response data was recorded both for reaction time (in milliseconds).

Procedure

Testing Block 1: Stroop Task & Cell- Phone Separation

Participants were asked to put their phone away in a provided basket. The basket was placed several feet from the participant and the participant was told that they will get their phone back immediately following the completion of the task. There was no engagement with the participants phone aside from asking the participant to place their phone in the provided basket. All participants sat at the computer and were asked to begin the stroop task. In the stroop task, participants saw words presented in a color and were asked to name the color of the word while ignoring the meaning of the word. Participants responded by speaking into a provided microphone. Response time and accuracy data were collected. Instructions were present on the screen beforehand followed by the real task. After sufficient time reading the instructions, participants proceeded to complete 4 blocks of the stroop task (each block contains 30 trials) resulting in a total of 120 trials per participant. Between each trial there was a brief break with a window that appeared on the screen asking participants to rest their eyes and proceed when they felt ready.

Block 2: Trivia Questionnaire followed by Standard Stroop

After completing the fourth block of the stroop task, participants were given back their phones and given a sheet of trivia based questions. Participants were asked to answer questions to the

best of their ability but were told they can google hard questions using their smartphones. Following completion of the trivia items, participants completed an additional 120 items of the stroop task.

Testing Block 3: Smartphone Specific Stroop Task

After completing the second testing block of the stroop task participants will be given the opportunity to take a brief break. After the break, participants were asked to put their smartphones back into the provided basket. Participants were then prompted to read instructions for the next task: “In this task you will see words of items you are likely familiar with.” “Please name the color of the word.” On the screen, a combination of neutral words not pertaining to smartphones (House, Key, Forest, Dog) will be displayed in different colors. Additionally, words relevant to smartphones such as: Message, Notification, Text, App were displayed in various colors. Participants were asked to name the color of the word while ignoring the word's meaning. Participants received 120 trial items during this block of the task. Following completion of Testing Block 3, a prompt was displayed on the screen stating “ thank you for your participation in this study.” At this point, participants have finished all blocks and trials of the stroop task. Participants were given their smartphone back. Participants were then given the smartphone addiction scale. Following this participants were debriefed and given complimentary candy.

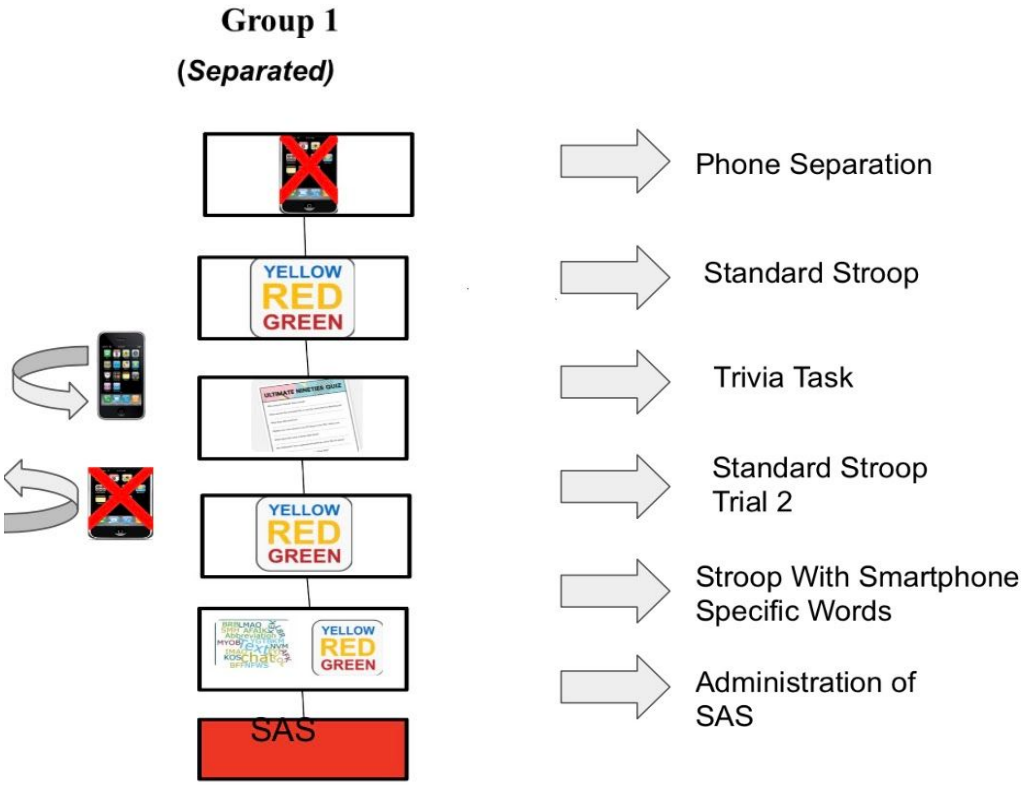

Figure 1: Flow diagram illustrating experiment process. Participants are first asked to place their smartphone in the provided basket. This is followed by completion of the first standard stroop task. Participants are then given back their phones and asked to complete a trivia task. Participants are again asked to place their phones in the provided basket, and are asked to complete another 120 trials of standard stroop. Upon completion of the second stroop task, participants are asked to complete a smartphone specific stroop task. Following this participants were given the smartphone addiction scale, which marked the end of the experiment.

Results

Score on the Smartphone Dependency Scale (SAS-R)

Across all participants the overall average score on the smartphone addiction scale was 31.7/60. On the original smartphone addiction scale the cut off score for smartphone dependency was set at 33/60 (Kwon et al., 2013). This suggests that the majority of participants in the present study, approached the cutoff for smartphone dependence according to the cutoff set by Kwon et al. However, given the small sample size, a median split was performed. The median SAS score obtained across all participants was 31.5. 10 out of 20 participants obtained a score higher than 31.5, suggesting that approximately half of participants were smartphone dependent.

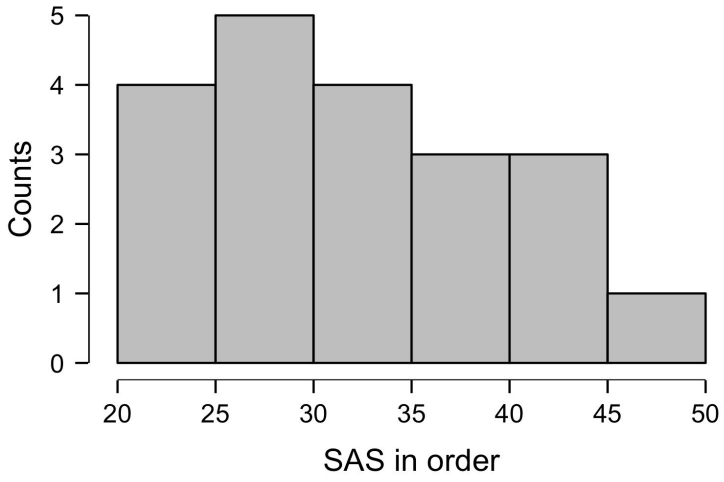

Figure 2: Frequency of SAS scores across participants. The Mean SAS score was 31.7/60 and the median score was 31.5. 10/20 participants exceeded the cutoff of 31.5/60 suggesting that half the participant sample scored at or above the cutoff score for smartphone dependence.

Congruency Effect within Blocks 1 & 2

A 2 congruency (congruent/incongruent) by 2 block (block 1/block 2) repeated measure ANOVA was used to determine if there was a main effect of congruency. A main effect of congruency was observed in block 1 (standard stroop task) of the experiment, ($F(1,18)=18.29$. $P<.001$), Indicating for standard stroop trails during block 1, participants response time (RT) was significantly slower in milliseconds for incongruent items (M= 840ms) compared to congruent Items (M=691ms) A congruency effect was also observed for block 2, ($F(1,18)=56.5$. $P<.001$, indicating for standard stroop trails during block 2, participants response time (RT) was significantly slower for incongruent items (M=790ms) compared to congruent Items (M=693ms)

N Participants= 20	**Block 1 Congruent Trials**	**Block 1 Incongruent Trials**	**Block 2 Congruent Trials**	**Block 2 Incongruent Trials**
Mean Reaction Time in Milliseconds	**691ms**	**840ms****	**693ms**	**790ms****
Total # of Congruent/Incongruent Items Per Block	**1060**	**1140**	**1080**	**1120**
Std. Deviation(ms)	**83ms**	**158ms**	**100ms**	**114ms**
Min (ms)	**508ms**	**559ms**	**514ms**	**522ms**
Max (ms)	**914ms**	**1200ms**	**942ms**	**991ms**
Average Percentage Accuracy on Items	**95%**	**93%**	**94%**	**93%**

*= Significance at .05 level

**=Significance at .01 level

Figure 3: Table illustrating participant sample size, mean reaction time in milliseconds(min,max & std), total number of congruent and incongruent items per block, and average percentage accuracy across blocks 1 & 2. Reaction time for incongruent trials was significantly slower compared to congruent trials. There was no statistically significant difference between accuracy across all blocks or trial type. Additionally the total number of congruent/items per block did not differ by block.

Smartphone Dependency by Congruency Interaction In Block 1

A 2 congruency (congruent/incongruent) by 2 dependency (dependant/not dependent) repeated measures ANOVA was used to determine a smartphone by dependency interaction across block 1. No smartphone dependency by congruency interaction was observed, ($F(1,18)=1.06$ $P=0.32$) reaction times for stroop items during block 1 for smartphone dependent individuals were not statistically different compared to non smartphone dependent individuals during block 1. For participants who did meet the cutoff score for smartphone dependency the mean reaction time for congruent items was 695ms. For non dependent users, the mean reaction time for congruent items was 692ms. For incongruent trials the mean reaction time for dependent individuals time was 778ms. For non dependent individuals the mean reaction time was 797 ms (See Figure 4 below).

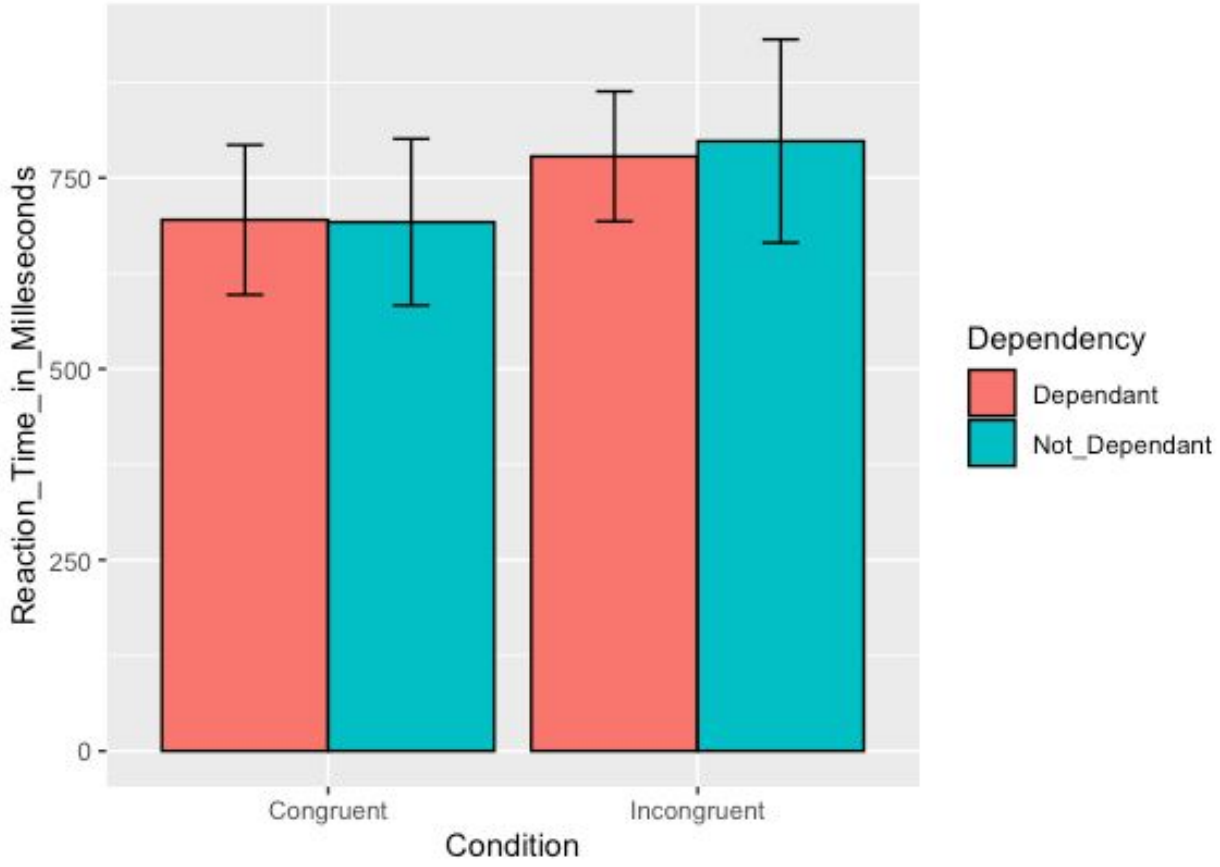

Figure 4: Block 1: reaction time on congruent and incongruent stroop trials in dependent and non dependant smartphone users. Reaction time for incongruent trials was significantly slower compared to congruent trials, however reaction times for congruent and incongruent trials did not differ significantly as a function of dependency.

Smartphone Dependency by Congruency Interaction In Block 2

A 2 congruency (congruent/not congruent) by 2 dependency (dependant/not dependent) repeated measures ANOVA was used to determine a smartphone by dependency interaction across block 2. No smartphone dependency by congruency interaction was observed for block 2: ($F(1,18)=0.78$ $P=0.39$ such that reactions times for smartphone dependant individuals for congruent trials (M= 713ms) was not significantly different compared to non dependent individuals (M=678ms) and reaction times for smartphone dependant individuals for incongruent

trials (M=821 ms) were not significantly different compared to non dependant individuals (

M=853) (See Figure 5 below)

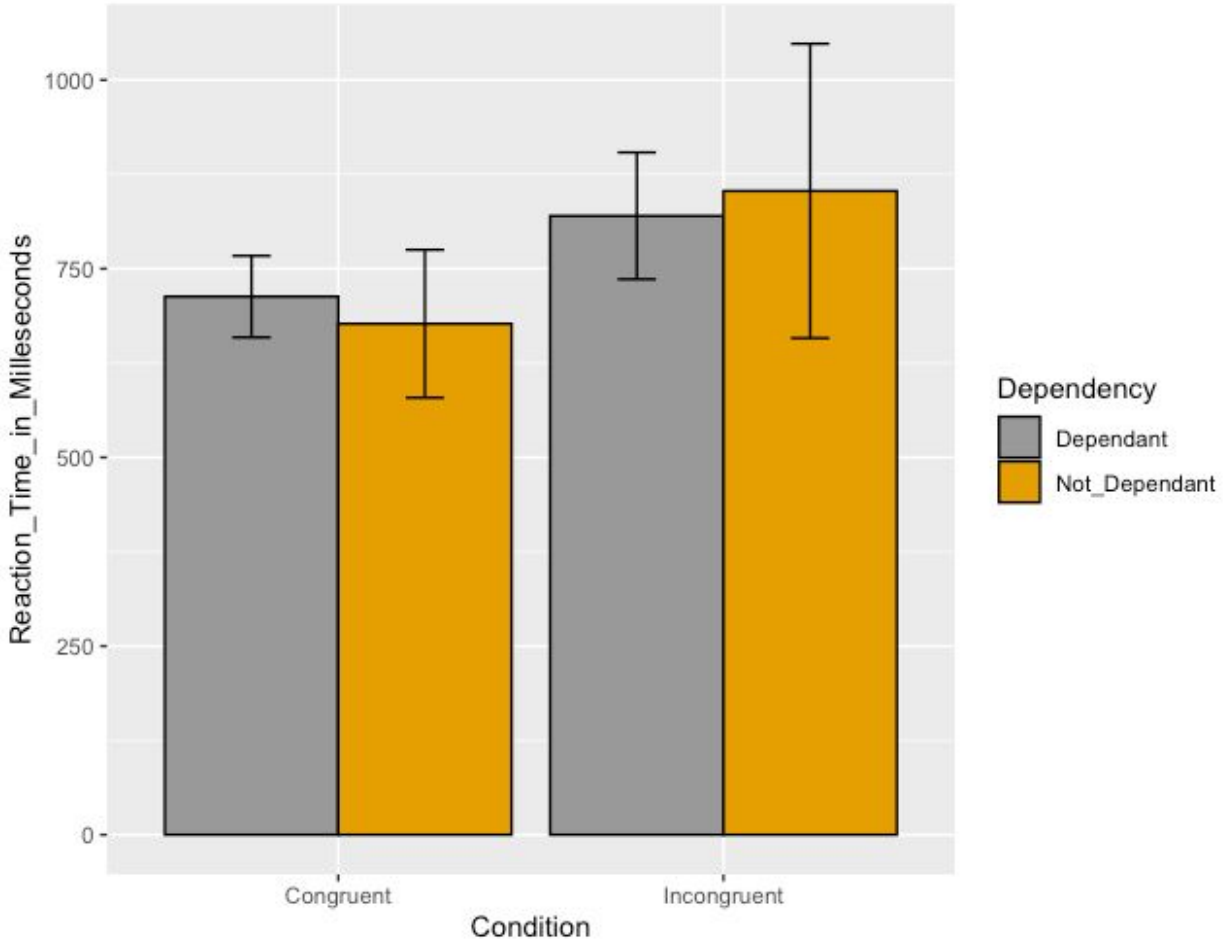

Figure 5: Block 2: reaction time on congruent and incongruent stroop trials in dependant and non dependant smartphone users. Reaction time for incongruent trials was significantly slower compared to congruent trials, however reaction times for congruent and incongruent trials did not differ significantly as a function of dependency.

Smartphone Dependency By Block Interaction

A 2 dependency (dependent/not dependent) by 2 block (block1/ block 2) repeated measures

ANOVA was used to determine a smartphone by dependency interaction across blocks 1 and 2.

A smartphone dependency by block interaction approached significance (F(1,17)= 3.221, *P*=.091 such that during block 1 reaction times in smartphone dependent individuals were faster (M=758ms) compared to non dependent individuals (M=836ms). Likewise during block 2, reaction times for dependent users were faster (M=626ms) compared to non dependent individuals (722ms). This was however not significant at the .05 level. (See Figure 6 below)

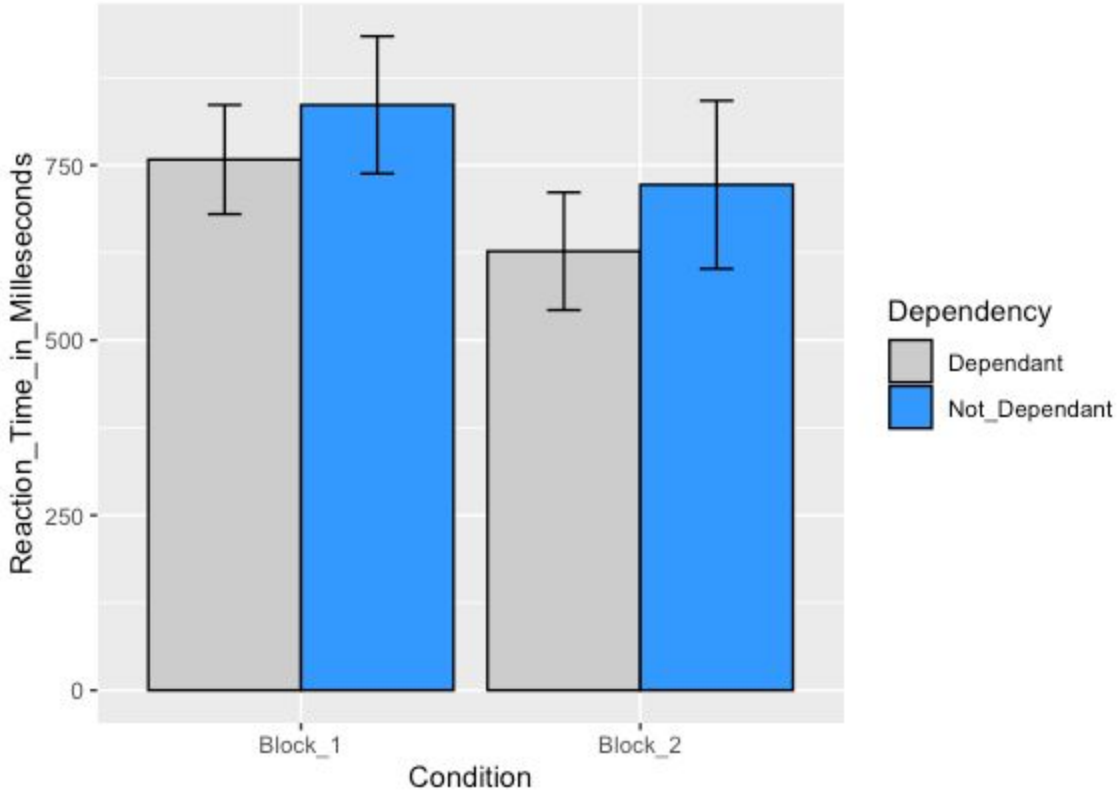

Figure 6: Comparison in reaction time on stroop items over the course of blocks 1 and 2 in dependent and non dependant smartphone users. Reaction times for non dependent individuals were slower than dependent individuals across both block 1 and block 2. The difference approached significance (*P*=.091) but was significant at the .05 level.

Effect of Smartphone Specific Words VS Neutral Items on the Smartphone Specific Stroop Task

Participants who did meet the cutoff score for smartphone dependence (>31.5/60) did not display statistically significant differences in reaction time compared to non dependent individuals. No main effect of stimuli type was found on block 3 ($F(1,18)=0.016$, $P= .90$ such that reaction time to neutral stimuli (M=793ms) did not differ significantly compared to phone related stimuli (M=795ms). Additionally no stimuli type by smartphone dependency interaction was observed ($F(1,18)=0.163$, $P=0.69$ such that reaction time on neutral item types for smartphone dependant individuals (M=783ms) did not differ from reaction times to neutral items for non dependant individuals (M=800ms) and reaction time to phone related stimuli among smartphone dependant individuals (M=801ms) did not differ significantly from non dependant individuals (791ms) (See Figure 7 below)

Stimuli Type	Dependent	Mean RT (ms)	SD	N Participants
Neutral Stimuli (House, Dog, Key, Forest)	**Yes**	**783**	**135**	**10**
	No	**800**	**102**	**10**
Phone Related Stimuli (App, Text, Message, Notification)	**Yes**	**801**	**112**	**10**
	No	**791**	**68**	**10**

Figure 7: Mean reaction time in milliseconds across smartphone dependant and non dependant individuals for neutral and phone related stroop items. There was no statistically significant difference between reaction time for neutral items vs phone related items. Finally there was no item type by dependency interaction.

Discussion

This study was designed to examine the relationship between smartphone dependency and selective attention performance. Selective attention was operationalized as performance on the stroop task. A traditional congruency effect was found such that reaction times for incongruent stroop items was slower then for congruent items. There was no main effect of smartphone dependency such that participants who met or exceeded the median split cutoff score on the SAS (>31.5) did not show differences in reaction time across all stroop items in block 1 and block 2. Additionally there was no main effect of block or a block by dependency interaction such that reaction times for stroop items In block 1 (in which participants were initially separated from their smartphones) did not significantly differ in terms reaction time during block 2 (following the trivia questionnaire). Additionally on the smartphone specific stroop task, there was no main effect of item type such that reaction time to neutral items (House, Dog, Key, Forest) did not significantly differ from reaction time to smartphone specific items (Text, App, Notification, Message). Finally there was no interaction between smartphone specific words and smartphone dependency such that reaction time for smartphone specific specific items (Text, Message, Notification, App) among smartphone dependant individuals did not significantly differ from participants who were not smartphone dependant.

Comparing block 1 to block 2, it seems participants were slower for items on block 1 but faster on block 2. Although not statistically significant the general trend of the data suggests that dependent individuals were faster than non dependent individuals on block 2 of the experiment for both congruent and incongruent trial types. This is contrary to the original hypothesis which was that reaction time would be slower during block 1 (after the trivia questionnaire), the logic

being that by using their phone briefly beforehand one might be distracted and thus perform worse on the subsequent attentional task. On block 2 participants seemed to perform better in terms of reaction time but did not show any differences in accuracy. The literature suggests that excessive smartphone use and smartphone separation negatively impacts cognitive performance especially executive functions (Baumgartner et al., 2014, Sherman et al., 2009). However Abrahmson et al. (2009) found that frequent media multitaskers (i.e. those who attend to multiple media devices at the same time while completing tasks) showed worse performance in terms of accuracy for stroop items but showed faster reaction time. Although in the present study participants did not show differences in accuracy betweens blocks, participants who were dependent seemed to perform slightly faster. It is possible participants improved their performance as a result of using their phone and completing the trivia questionnaire consisting of general knowledge and vocabulary questions. As noted in the method section after completing block 1, participants were asked to complete a trivia questionnaire in which they were given back their smartphone. It is possible that phone use, specifically for learning new information, stimulated focus and attention which subsequently increased their performance on the following stroop block. However, this is largely speculation, and follow up data is needed to examine if there is indeed a relationship.

Limitations of Study

There were several limitations in this study. Firstly, the study had a small sample size (N=20). Prior to beginning the study the goal was to have a minimum of 40 participants. However due extreme circumstances and college closure due the corona virus outbreak data was only collected

from 20 individuals. Statistically speaking, a low sample size decreases power, and decreases margin for error. It is possible that the lack of some statistically significant findings can be partially attributed to the small sample size. A follow up study with a sufficient sample size of at least 40 participants is necessary to illustrate this.

Another limitation was the dependence on the stroop tasks as the only measure of selective attention. In this study selective attention was operationalized as performance on the stroop task, a task of response control in which the participant has to name the color of a provided word while inhibiting the words meaning. However, there are a variety of other tests of selective attention that could also be used in this study. Additional tests of executive functioning include working memory based tasks such the digit span task and N-back tests of working memory. Uncapher et al (2015). found that frequent media multitaskers showed decreased working memory performance, however there is still limited research on how smartphone dependency impacts working memory performance. In a follow up study, it would be helpful to utilize working memory based tasks in addition to selective attention tasks. By providing a battery of additional assessment of selective attention, it would be possible to get a more thorough understanding of how smartphone dependence, usage, and separation impacts selective attention performance across a variety of domains.

In this study the primary outcome measure for smartphone dependence was the participants score on a revised version of the smartphone addiction scale (SAS), developed by Kwon et al. (2013). The scale consists of 10 questions in which the participants rate (on a scale from 1-6) how much they agree or disagree with the statement above regarding their relationship with their smartphone. Reliance on self report measures while a fast and effective way of getting

data from the participant have several limitations. Firstly the response individuals provide to questions are often biased by their own history and experience. In the case of smartphone habits, which is a personal topic participants might have been inclined to under/overestimate their responses to the questions, which affects the validity of the data. Another potential drawback with self report data, specifically in the context of the SAS scale is the issue with its rating scale. The SAS scale quantifies smartphone dependency from a 1-6 scale 1 being strongly disagree , 2 being disagree, 3 being weakly disagree, 4 being weakly agree, 5 being agree, and 6 being strongly disagree, with a question such as "I feel impatient and fretful when I am not holding my smartphone." Given the rating scale, it might be difficult to quantify and discriminate between strong disagreement and weak disagreement. In a revised follow up study, it might be beneficial to alter the phrasing and scoring of the SAS, perhaps replacing weakly agree/weakly disagree items with neutral or neither agree nor disagree. This might allow for participants to better discriminate and choose between rating scores. It is also necessary to note that certain items on the SAS are phrased in a way that might affect the response of the participants. Certain questions such as "I can't live without my smart smartphone" are somewhat extreme. Given the extreme nature of how the question is phrased participants might feel threatened by the question, and answer more conservatively, ultimately affecting their overall result on the SAS. In a follow up study it might be necessary to rephrase questions from the SAS. Perhaps "I can't live without my smartphone" could be rewritten as " I find it difficult seperate from my smartphone after I start using it". Questions phrased in a less direct and threatening way, might allow participants who respond to the questions more objectively.

Following the completion of block 1 standard stroop trials, participants were administered a trivia questionnaire consisting of 10 general knowledge questions. The primary intent of this questionnaire was to have participants use their smartphones to facilitate active smartphone usage, prior to putting their phones away again, before beginning block 2. The usage of the trivia questionnaire was largely influenced by the finding of Sparrow et al. (2011). Sparrow et al. (2011) described a form of internet amnesia such that individuals have a tendency to quickly forget information that they look up and online. Although the present study did not intend to investigate memory performance as it relates retrieval of searched information on the internet, it was hypothesised that this same diminishing in performance after looking up readily available information would in some way negatively impact attention. It was hypothesised that by facilitating smartphone usage in dependant individuals, participants would show worse performance on block 2 standard stroop trials, however the results suggest no real difference in performance on block 2 compared to block 1, and no interaction between block and dependence suggesting that the trivia questionnaire in itself, might not have influenced performance in the way it was initially intended to. Although not statistically significant both dependent and non dependent individuals were faster on stroop items on block 2 compared to block 1 possibly indicating that after taking the trivia questionnaire participants showed improved attention, however a larger sample size, and follow up of study is needed to determine if there is indeed an effect.

Directions for future research

In a future study it would be helpful to make several changes to the method of the current study to more adequately assess the relationship between smartphone separation and dependency on

selective attention. As mentioned earlier it will be necessary to develop a revised variant of the smartphone addiction scale (SAS), that utilizes less extreme scale ratings and that phrases the questions in a way that is less threatening. An example of an extreme question on the questionnaire as follows: "I will never stop using my smartphone even if it greatly affects my daily life." The usage of the word never is somewhat extreme and implies that the user will continuously use their phone without stopping. As a revision, replacing "I will never stop" with "I have difficulty stopping" leaves the question more open ended and may allow the participant to more accurately assess when they use or stop using their phone. In order to quantify how extreme some of the questions are on the original SAS, I propose a pilot study in which a separate group of participants will be asked to rate how extreme and how likely those participants are to answer honestly to the provided question. Based on the data received in the pilot study, revised questions will be sent out in which participants will again rate how extreme the questions are and how likely they are to answer honestly to the question. The goal would be to maximize honest answering while minimizing how extreme the question is.

In addition to a revised version of the smartphone addiction scale, in a future study it would be helpful to include others measure anxiety pertaining to smartphone use, specifically physiological measures of anxiety as it relates to smartphone separation and usage. As mentioned before, research suggests that students who were unable to attend to incoming cell phone notification/answer a phone call showed significantly elevated levels in blood pressure. (Clayton et al., 2015). This signifies that separation from one's cellphone results in changes in physiological symptoms. In a future study, it may be helpful to include additional physiological measures such as changes in heart rate, changes in blood pressures, and galvanic response (

which measures physiological stress as a function of skin conductance). In the context of the present study, anxiety due to smartphone separation could be partially measured by comparing baseline blood pressure, heart rate, and skin conductance prior to smartphone separation to blood pressure, heart rate, and skin conductance after completing the stroop trials across each of the 3 blocks.

In addition to utilizing physiological measures of anxiety as it relates to smartphone dependence and separation, there is limited research on how smartphone dependency and usage of technology impacts the brain on neurobiological level. It is known that substance based addiction and dependency have neurobiological correlates. For example misuse of drugs like cocaine and methamphetamine, can result in physiological dependence by which excessive dopamine is released. As a result of excess dopamine release the brain becomes habituated to higher levels of the dopamine, resulting in needing the drug to maintain homeostasis. Without using the drug on a consistent basis the dependent individual will suffer withdrawal symptoms, ranging anywhere from extreme nausea to deadly seizures as a result of chemical imbalances, due to abruptly stopping use. In the case of non substance based dependency such as smartphone dependence there is some but limited evidence on how exactly overuse of mobile technology and a smartphone can impact the brain at the neurochemical level. A 2017 study in South Korea investigated the relationship between smartphone dependency quantified by scores on questionnaires and self report surveys, and neurochemical changes in the brains of young adults. Utilizing magnetic resonance spectroscopy (MRS) the researchers were able to to observe changes in the brain's chemical composition, with specific attention to Glutamate (the brain's primary excitatory neurotransmitter) and GABA (the primary inhibitory neurotransmitter). The

researchers found that participants who were dependent on their smartphones and mobile technology showed high ratio levels of GABA to Glutamate in the anterior cingulate cortex (acc) compared to healthy controls (Seo, Jeong, Choi, Kwon, Park,& Kim 2017). Research suggests that proper regulation of GABA in the brain is important for higher order cortical functions such as visual processing and visual motor skills, and emotional regulation such as in managing anxiety and depression. Smartphone dependent participants with higher GABA levels also showed higher rating of depression and anxiety, suggestive of a possible link between GABA dysregulation, smartphone dependence, and problems with mental status such as anxiety and depression (Seo et al., 2017). Given the scope of the present study which was to investigate the relationship between smartphone dependency and selective attention, a possible future study might involve investigating how brain activity (perhaps utilizing fmri) differs between smartphone dependent individuals and non-dependant individuals (controls) while they complete a battery of selective attention tasks. This can include tasks like the stroop tasks and other tasks which test executive functioning such as the trail making task, digit span tasks, and wisconsin card sorting tasks. Using fmri, levels of oxygenated blood flow in dependent individuals will be compared to controls both at baseline and after while they complete the various executive function tasks. It will be hypothesised that dependent individuals will show different patterns of activation (primarily in the frontal lobes) compared to non dependent individuals.

Conclusion

The present study examined the impact of smartphone dependency on selective attention attention performance, and sought to determine if greater dependence on smartphones negatively impacted performance on the stroop response inhibition task, which measures inhibitory control and ability to sustain attention. The majority of prior study suggests that excessive smartphone use, usage of a smartphone while completing a cognitively demanding task, and subsequent separation from a smartphone prior to engaging in a task, can negatively impact one's performance. In the present study it was hypothesised that participants who were separated from their smartphones and met or exceeded the cutoff score for smartphone dependency on the SAS would perform worse across both blocks of the stroop tasks compared to individuals who were not smartphone dependent. Additionally it was also hypothesised that after completing block 1 and finishing a brief trivia questionnaire, participants who were smartphone dependent would perform even worse on block 2 stroop trials. Finally It was hypothesised that on block 3, smartphone dependent individuals would show worse performance on smartphone specific words (App, Notification, Text, Message) compared to neutral word items (Forest, Dog, House Key). The results of the data indicate that there was indeed a congruency effect across blocks 1 and 2 such that reaction time for incongruent word/color pairs was slower compared to congruent word/color pairs. No dependency by block interaction was found such that smartphone dependent individuals did not show worse performance in terms of reaction time and accuracy on stroop items across blocks 1 and 2. Finally regarding block 3, smartphone dependent individuals did not show worse performance in terms of reaction time for smartphone specific items compared to neutral items. Although the majority of findings in the present study did not yield a

statistically significant result, these findings are important in that they add to the limited literature on how smartphone dependency impacts cognitive performance and mental health. There were a number of limitations that might have contributed to null findings in this study, as mentioned due to extreme circumstances, there was a limited sample size of 20 participants, which limited the power of the study. In a potential follow up to this study it would be helpful to have a larger sample size. Additionally for future research it might be helpful to evaluate smartphone dependency not only using self report methods (such as with the SAS) but with physiological measures of distress (such as changes in heart rate, blood pressure and skin conductance). Finally given the limited amount of research examining neurobiological and neurochemical impacts of mobile technology use on the brain, it would be useful to have a study which examines the impact of smartphone dependency, seperation, and usage during a cognitively demanding task on neural activation across different brain regions task to shed light on how smartphone dependency manifests at the neurobiological level.

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Appendix A:

Bard College

Psychology Program

Consent Form

Principal Investigator

Immanuel Zion

Psychology Program

Bard College

Project Title

The Effects of Smartphone Separation on Selective Attention

Introduction

You are being asked to be a volunteer in a research study in the Psychology Program at Bard College. Please read the following information carefully and feel free to ask questions if any of the information is unclear.

Purpose

The purpose of this research study is to better understand how smartphone usage and smartphone habits effects performance on attention and cognitive performance.

Study Procedure

If you decide to participate, you will be asked to complete a questionnaire that provides us with basic demographic information including your age and gender. You will then be asked to complete a survey assessing your daily smartphone usage and habits. Next, you will be asked to complete several trials of a computer based test of selective attention. Finally, you will be asked to answer several trivia questions, followed by one computer based selective attention task. The total duration of the experiment will be approximately 45 minutes, and you are free to withdraw from the study at any time.

Risks and Discomforts

There is minimal potential risk and discomfort from participating in this study. The risks are no greater than those involved in daily computer based activities such as eye strain.

Benefits

You are not likely to benefit directly from participating in this study. However, the data from this study will help us learn more about to what degree smartphone dependence and subsequent separation impacts our attention.

Compensation

You will be compensated through the chance to win 1 of 3 $50 dollar amazon gift cards. If you decide to withdraw from the study at any time, you will no longer be able to win the gift cards, but will receive complimentary candy. Participation in the study is entirely voluntary and you can withdraw at any time.

Exclusion/Inclusion Criteria

Participants in this study must be college students between the ages of 18 – 30.

Confidentiality

Several procedures will be followed to keep your personal information confidential. Your records will be kept under a code number rather than by name. This consent form is the only form associated with this research study that contains your name. Your data will be under a unique ID number. At the completion of your participation, the data associated with your performance and the questionnaire responses will be separated from this consent form. After doing so, it will be very difficult to link your name to any of the data that you provide. In addition, your records will be kept in locked file cabinets and password protected datasets. Only study staff will have access to these records. Your name will not appear when the results of this study are presented or published. Your privacy will be protected to the extent provided by law.

To ensure that this research is carried out in the proper way, the Bard College IRB may review study records.

In Case of Injury/Harm

If you are injured as a result of being in this study please contact the Principal Investigator, Immanuel Zion at iz7950@bard.edu ,or 9178683103.

Participant Rights

Your participation in this study is voluntary. Neither refusal to participate nor participation discontinued at any time will invoke penalty or loss of benefits to which the subject is otherwise entitled.

Questions about your Rights as a Research Participant

If you have any questions about your rights as a research participant, you may contact the chair of the Bard College IRB at irb@bard.edu.

Questions about the Study

If you have any questions, you may contact Immanuel Zion at iz7950@bard.edu or 9178683103.

If you sign this form it means that you have read (or have had read to you) the information given in this consent form, and would like to be a volunteer in this research study.

_____

Participant Name (printed)

_____

Participant Signature Date

_____

Signature of Person Obtaining Consent Date

Appendix B:

Demographic Questionnaire

Name

Age

Year (Please circle)

Freshmen , Sophomore, Junior, Senior, Fifth Year

Gender Identity

Do you Wear Glasses or Contacts?

Yes/ No

Are you currently using a hearing aid?

Yes/no

What is your first language?

What other languages are you fluent In?

Appendix C:

Smartphone Usage & Habits Questionnaire

1: I use my smartphone longer then I intend to

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

2: I feel that I miss plans or work due to excessive smartphone usage

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

3: I have a difficult time concentrating in class, doing assignments, or while working due to smartphone use

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

4: I sometimes experience discomfort in the wrists, neck or back while using a smartphone

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree

1	**2**	**3**	**4**	**5**	**6**

5: I cannot stand not having my Smartphone

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

6: I feel impatient and fretful when I am not holding my smartphone

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

7: I have my smartphone on my mind even when I am not using it

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

8: I will never stop using my smartphone even if it greatly affects my daily life

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

9 : ***I constantly check my smartphone so I don't miss out on conversations between people on social media such as facebook, instagram or twitter***

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

10: ***The people around me tell me that I use my smartphone too much***

Strongly Disagree	Disagree	Weakly Disagree	Weakly Agree	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**	**6**

Appendix D:

Trivia Questionnaire

Directions: Please answer the following 10 questions to the best of your ability. Feel free to use your smartphone to look up answers you cannot answer on your own.

1: How many states are there in the USA?

2: What is the capital of New York State

3: How many sides are there on a pentagon?

4: What does Inchoate mean?

5: What does Uncanny mean?

6: What does the Scoville Scale measure?

7: What does Dilatory mean?

8: What is the capital of Kenya?

9: Orthoepy is the study of what?

10: What creatures do Ichthyologists study?

Appendix E:

Trivia Questionnaire (KEY)

Directions: Please Answer The Following 10 Questions to the best of your ability. Feel free to use your smartphone to look up answers you cannot answer on your own.

1: How many states are there in the USA?

50

2: What is the capital of New York State

Albany

3: How many sides are there on a pentagon?

5

4: What does Inchoate mean?

Just Begun/not Fully Developed

5: What does Uncanny mean?

Strange/Mysterious in an unsettling way

6: What does the Scoville Scale measure?

Spiciness/Heat

7: What does Dilatory mean?

Tendency to Delay/Procrastinate

8: What is the capital of Kenya?

Nairobi

9: Orthoepy is the study of what?
The pronunciation of a particular language

10: What Creatures do Ichthyologists study.
Fish

Appendix F:

Debriefing Statement

Thank you for your participation! In the current study, we were interested in understanding the effects of smartphone dependence and subsequent separation on selective attention. We predicted that separation from one's smartphone would lead to more distraction, and subsequently worse performance on the Stroop task. In addition, we were interested in assessing to what extent mobile cell phones affect performance and functioning both in and outside of the classroom, and whether or not studying with your smartphone is an optimal decision, given one's relationship with their phone.

If you have any additional questions, please ask the experimenter at this time, or you may contact the primary investigator, Immanuel Zion (iz7950@bard.edu).

Appendix G:

IRB Approval

Bard College

Institutional Review Board

Date: November 18, 2019
To: Immanuel Zion
Cc: Thomas Hutcheon, Deborah Treadway
From: Laura Kunreuther, IRB Chair
Re: "The Effects of Smartphone Separation on Selective Attention"

DECISION: APPROVED with minor change

Dear Immanuel,

The Bard Institutional Review Board reviewed your proposal under expedited category 7,

> (i) Research activities that present no more than minimal risk to human subjects, and
>
> (ii) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

We only suggest that you adjust the time required (on consent form) to approximately 1 hour to be more realistic. Contingent on this small change, your proposal is approved through November 18, 2020. Your case number is 2019NOV18-ZIO.

Please notify the IRB if your methodology changes or unexpected events arise.

We wish you the best of luck with your research.

Laura Kunreuther
IRB Chair