Margrethe Rapp Stavrum

Testing the Brain Drain Hypothesis

Effects of the smartphone's presence on working memory

Master's thesis in Psychology
Supervisor: Hermundur Sigmundsson
October 2020

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Preface and Acknowledgements

The present work took place at the Department of Psychology, Norwegian University of Science and Technology (NTNU). The current thesis started with genuine curiosity and some concern for the technology's impact on the human mind and functioning.
The author of the current study has been responsible for developing research questions, collecting and analyzing the data.

I want to express gratitude towards my supervisor, Hermundur Sigmundsson (NTNU), for his guidance, advice and assistance during this master's thesis. I would also like to thank Adrian Dybfest Eriksen (NTNU) for feedback and help with the Spanboard test, and Håvard Lorås (NTNU) for guidance on the SPM test. Learning from and working with such competent and skilled persons has been a privilege.

To all the participants, thank you for your time, your cooperation and your contributions so this study could be realized. I am also grateful for the Department of Psychology's administration for their help with practical issues, such as using the lab and their positive attitude.

Last, I would like to thank my friends and family for their support and love. A special thank you to my partner for your encouragement, for sharing your optimism and persistence over the past months.

Margrethe Rapp Stavrum, Trondheim, October 2020

"Nothing in life is to be feared. It is only to be understood."

Marie Curie

Sammendrag

Denne studien startet med en nysgjerrighet rundt menneskers interaksjon med smarttelefoner. Forskningsdesignet brukt for å undersøke dette ble påvirket av arbeidet til Ward, Duke, Gneezy, og Bos (2017) i deres studie om Brain Drain hypotesen: «tilstedeværelsen av ens egen smarttelefon kan okkupere kognitive ressurser med begrenset-kapasitet og slik gjøre færre ressurser tilgjengelig for andre oppgaver, og underkutte kognitiv prestasjon.» Nåværende studie etterstreber å utforske denne hypotesen med et innen-gruppe eksperiment med et utvalg av norske universitetsstudenter. Ved første oppmøte ble deltakerne ($N = 40$) tilfeldig delt inn i to forskjellige start-betingelser; smarttelefonen i nærheten eller ute av rommet. Deltakerne utførte så Spanboard og Raven's Standard Progressive Matrices. Alle deltakere fikk motsatt betingelse på den siste deltakelsen. På slutten av siste deltakelse gjennomførte de en kort spørreundersøkelse rundt tilknytning og avhengighet til smarttelefon. Funnene indikerer at det ikke var en statistisk signifikant forskjell i prestasjon når smarttelefonen var til stede sammenlignet med når den var ute av rommet på de to kognitive testene.

Nøkkelord: Smarttelefon, visuospatielt arbeidsminne, Brain Drain hypotesen, kognisjon

Abstract

The current study started with a curiosity towards human interaction with smartphones. To investigate this, this study was influenced by the work of Ward, Duke, Gneezy, and Bos (2017) in their study on the Brain Drain hypothesis: the mere presence of one's own smartphone may occupy limited-capacity cognitive resources and thereby leave fewer resources available for other tasks and undercut cognitive performance. The current thesis strived to investigate this hypothesis using a within-subjects experiment on a sample of Norwegian university students. The participants ($N = 40$) were randomly assigned to two different start conditions: the smartphone in the near presence or outside the room while conducting the Spanboard task and the Raven's Standard Progressive Matrices. All participants received the opposite condition on their second trial. At the end of the second trial, a 13-Item Phone Attachment and Dependency Inventory was administered. The findings indicate no statistically significant difference in performance when the smartphone was nearby compared to out of the room in any of the tasks.

Keywords: Smartphone, visuospatial working memory, Brain Drain hypothesis, cognition

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Introduction

Over the past 25 years, the use of Internet has increased immensely (Pew Research Center, 2020), and alongside the use of computers and smartphones, has developed just as extensively (Pew Research Center, 2018). Research in the use of technology has increased greatly, yet, the real impact of smartphones on mental health, social lives, and work performance is in its mere inception. Initially, the computer was a tool for e-mailing and text editing amongst other tasks. It was stationary and consequently limited to how and when it could be used. Today the computer is in our hands, with all the tools in our pockets. The areas of use have expanded, from a more professional sphere, drifting over to a mix of both work and social life. The social networking sites (SNS) (Kuss & Griffiths, 2011) has contributed to this shift, and for the many media companies (i.e., Instagram, Youtube, Facebook), the social and private sphere brings in a lot of money (Statista, 2020). A substantial part of the income is through advertisement (Facebook, 2019; Alphabet, 2019; Statista, 2019). Being online on social media, one will be presented with tailored advertisement, and the longer one can keep people online and active on their SNS, the more money it is possible to earn (Alphabet, 2019; Investopedia, 2020). In this private sphere for chatting and picture-liking, the technology used is designed to keep peoples' attention (Kujala et al., 2011; Jokinen et al., 2018). It is possible that more knowledge and facts about smartphone use can shape how these devices and its content are developed. Hence, keeping people more aware of possible side effects of using these devices. Today, there are some regulations in favor of consumers, the Data Protection Act was introduced in 1998 and in 2018 renewed by the General Data Protection Regulation (General Data Protection Regulation, 2020). Researching the effects smartphones and smart devices has on human functioning are relatively new considering these devices have existed the last two decades. In 2019, the World Health Organization emphasized the lack of research on screen time among children, making a clear signal that it is critical to investigate connections between physical and mental health, and smart device usage (World Health Organization, 2019).

The main purpose of this study is to test the Brain Drain hypothesis, as presented by Ward et al. (2017a). Their hypothesis suggests that "the mere presence of one's own smartphone may occupy limited-capacity cognitive resources and thereby leave fewer resources available for other tasks and undercut cognitive performance" (Ward et al., 2017a).

The research field on how humans are affected by smartphone use is increasing but there is still a need for more data to reach a certain conclusion.

The Smartphone

For many people, the myriad of functions and applications make it desirable to often keep the smartphone nearby. In Norway, 9 out of 10 (ages 9-79 years old) reported they used Internet on a daily basis in 2018 (Statistics Norway, 2020a). In the Norwegian population, 35% also reported playing a digital game each day. (Statistics Norway, 2020a). The numbers for those using Internet on their cell phone in Norway were 85% for 2019 (Statistics Norway, 2020a). All though it does not specify what kind of cell phone, it is fair to assume most of these people have some sort of smartphone to be able to use Internet. Similarly high numbers are also found in other countries, by example 81% of Americans owned a smartphone in 2019 (Pew Research Center, 2019). Access to SNS through smartphones' applications has made these platforms tremendously popular in the last decade. In the USA, 90% of young adults use at least one SNS (Pew Research Center, 2019). Today, young people use their smartphones as a source for entertainment and social interactions. Social media and online games are platforms where one can make new acquaintances. Those who have grown up with the Internet and smart devices are called digital natives (Cambridge Dictionary, n.d.). This type of smartphone use is not limited to young people, but they tend to use it more than most adults (age 30-49), where 92% (age 50-64, 79%) own a smartphone (Pew Research Center, 2019). The convenient availability with 4G/5G network and wi-fi on smartphones, makes it possible to be online around the clock. The social nature of humans seems to be part of a fundamental need to belong in a group (Baumeister & Leary, 1995). This need for belonging is linked to our cognitive and emotional functioning, general health and well-being (Baumeister & Leary, 1995). Combining the smartphones functions and human needs gives the smartphone a unique impact on people's everyday life. Having these functions (i.e., gaming and SNS) so readily available enables us to stay in touch with our friends and family and thus fulfills a fundamental need.

Research on smartphones and cognition. Smartphones seemingly have an unlimited capacity to entertain us and work for us. It offers external memory storage and aids in searching for information considerably. One can access search engines through both computers and smartphones, making it very easy to find information when needed. Sparrow et al. (2011) studied how using search engines like Google, may affect humans' cognition. Their findings imply that people seemed primed to think about computers when confronted with tricky questions. Furthermore, lower recall rates of the information itself were found when people expected to have future access to this information (Sparrow et al., 2011). Instead of recalling the actual information itself, people showed an enhanced ability to recall where to access the information. The researchers suggest there has arisen a symbiotic relationship with computer tools and applications and thus, some dependency to these devices (Sparrow et al., 2011). Thornton et al. (2014) investigated whether the mere presence of the cell phone could interfere people's attention and task performance. The results revealed no distracting effect on simple tasks, however, they observed significant distracting effects on more complex tasks (Thornton et al., 2014). The study on the Brain Drain hypothesis (Ward et al., 2017a) supports the suggestion that a device like the cell phone; the smartphone, may have properties that distracts aspects of the human cognition. Ward et al. (2017a) tested performance on cognitive functions, such as working memory capacity and fluid intelligence, under three smartphone conditions. They conducted a replication of the first experiment, using slightly different measures. Their findings support their hypothesis, that "the mere presence of one's own smartphone may occupy limited-capacity cognitive resources and thereby leave fewer resources available for other tasks and undercut cognitive performance" (Ward et al., 2017a). There seems to be a general perception that smartphones can be a source of disturbance. Today, there are even applications that lock down the smartphone for a specified amount of time to help increase productivity. One example is the application Hold, users earn points by not using the phone while it is locked and the points can be traded in gift cards or free items (Hold, 2020).

Other research on cognition and smartphones has showed that adolescents might affect each other by looking at behavioral and neural responses to "likes" aided by and fMRI paradigm developed to simulate Instagram (Sherman et al., 2016). While looking at pictures with many likes compared to few likes, there were registered higher activity in brain areas for reward, social cognition, imitation and attention. The results showed that the adolescents would rather give likes to pictures already having many likes compared to those with fewer likes (Sherman et al., 2016). This was applicable for neutral pictures and pictures showing risky behavior, and Sherman et al. (2016) suggests that these findings show some of the mechanisms involved when your behavior are being affected by your peers. A mismatch has been claimed between behaviors that form and maintain social relationships, and smartphones (Sbarra et al., 2019). They labelled this specific interference technoference, and it is defined "as the ways in which the smartphone use may interfere with or intrude into everyday social interactions" (Sbarra et al., 2019).

It may also seem that the term technoference applies to social settings with strangers. An interesting study on approach-oriented behaviors like smiling found that the smartphone has a negative effect on the display rate of smiles (Kushlev et al., 2019). They point out that the progress of technology has enabled us the capacity of “absent presence”. Amongst strangers they reported significantly fewer smiles if they used their smartphones compared to the group of strangers not using their smartphone (Kushlev et al., 2019). They also reported a large difference in interaction between the groups, clearly showing that those who did not have their smartphone interacted a lot more than those with their smartphone. Despite humans needs, social settings can also be stressful for some. Hunter et al. (2018) addressed the psychological and physical stress that might arise from social rejection. Their results indicate that stress reactions linked to social rejection were less apparent for those with access to their smartphone (Hunter et al., 2018). They did not have to use the smartphone to find this effect, the presence of the smartphone was enough. Hunter et al. (2018) proposed that the smartphone can act like a social safety buffer, or a digital security blanket. There are many studies regarding smartphone use, cognition and behavior. Wilmer et al. (2017) reviewed studies assessing smartphone habits and cognitive functioning. By exploring the findings regarding the consequences of typical everyday usage of smartphones, they found that memory and knowledge has some significant findings in both directions. Thus, they conclude on this basis that precautions should be taken when using smartphones in your everyday life (Wilmer et al., 2017).

Research on problematic smartphone use. Some of the greatest concerns regarding smartphone use is linked to possible negative outcomes due to the increased use among all ages (Pew Research Center, 2019). Studies have found that problematic use of smartphones can be associated with poor sleep quality (e.g., Cárthaig et al., 2020; Yang et al., 2020) and depression and anxiety (Yang et al., 2020). Excessive use of SNS or smartphone applications (Montag et al., 2018), and online gaming platforms (Andreassen et al., 2016) can create addiction for some of the users. Some of the worst consequences of smartphone usage could be addiction to the smartphone (Andreassen, 2015). It has also been observed that that those who seek social relations are more inclined to become addicted to social media (Andreassen, Pallesen and Griffiths, 2017). They looked at the relations between addictive use of social media, narcissism and self-esteem by conducting a SNS addiction survey (Bergen Social Media Addiction Scale, (Narcissism Personality Inventory, and Rosenberg Self-Esteem Scale). The results indicated there might be a greater likelihood for high scores on BSMAS by being female, single, student lower income, low self-esteem and age amongst other things

(Andreassen et al., 2017). According to the researcher this might indicated that by being female one is more liable to addictive behavior that includes social relations (Andreassen et al., 2017). The complexity between humans and the use of the Internet is present in every part of our lives and somewhat hard to resist according to Montag and Diefenbach (2018). Distancing from the Internet and smartphone with its social networking sites (SNS), almost equals social distancing, resulting in not being connected to the Internet. For many, that is a price too high to pay even though being connected all times might also be a high cost in their everyday life (Montag & Diefenbach, 2018). These might be underlying mechanisms that affect our day to day interaction with the smartphone. One study showed that heavy smartphone use could mean a reduced capacity to process information, and an increase in impulsive and hyperactive behavior, when comparing to non-users (Hadar et al., 2015).

Marty-Dugas and Smilek (2020) examined how general and absent-minded smartphone use could relate to both negative (i.e. depression, anxiety, stress, negative affect) and positive outcomes (i.e. positive affect and flow). Absent-minded smartphone use was revealed to be a predictor of negative outcomes (Marty-Dugas &Smilek, 2020). They point out that addiction in general has a comorbidity with other mental health issues, and therefore it might not be surprising that measures of smartphone addiction positively correlates with mental illnesses like anxiety and depression (Marty-Dugas & Smilek, 2020).
In 2019, WHO linked sedentary lifestyle and increased risk of obesity in children to screen time. In 2016, 39% of adults (over the age of 18) were overweight, and 13% obese worldwide (World Health Organization, 2016). Higher activity levels can on the other hand protect those who are vulnerable to developing depression disorders, and researchers have found a connection between higher activity levels and fewer symptoms of major depression disorder in Norwegian children age 6-10 years old (Zahl, Steinsbekk & Wichstrøm, 2016).

There are reasons to also take into consideration that research on smartphones is relatively new. More empirical evidence is needed to establish a united understanding of the effects of the smartphone and digital technology (Bell, Bishop, & Przybylski 2015; Wilmer et al., 2017) and psychological well-being is urged by Orben and Pryzbylski (2019), based on the complexity of human behavior in interaction with digital technology.

Measuring smartphone dependency. Over the years, there has been developed several self-report questionnaires to investigate psychological effects of using the Internet, mobile phones and smartphones. Questionnaires are a popular tool to investigate psychological concepts of digital dependency or addiction. These questionnaires explore the individuals' involvement in Internet use; the Young's Internet addiction test (Young, 1998), mobile phone involvement questionnaire (MPIQ) by Walsh et al. (2010): Some test the dependency to the mobile; test of mobile phone dependency (TMD) by Chóliz (2012), and the nomophobia questionnaire (NMP-Q) (Yildirim & Correia, 2015). Some of the questionnaires examines addiction to social media applications and smartphones; the Bergen Social Media Addiction Scale (BSMAS) by Andreassen and colleagues (Andreassen et al., 2012; Andreassen et al., 2017), the Smartphone Addiction Scale (SAS) developed by Kwon et al. (2013), and the smartphone application based addiction scale (SABAS) by Csibi et al. (2016). In the study by Ward et al. (2017a), the questions used in the inventory to examine smartphone attachment and dependency has similarities to many of the mentioned questionnaires. Such as questions regarding if there are emotions like loneliness involved in using the mobile phone or smartphone (Chóliz, 2012; Ward et al. 2017b), and emotional aspects revealing some forms of dependency to the smartphone (i.e., nervous, anxious or frustrated) if one cannot use the smartphone as wanted/expected (Walsh et al., 2010; Yildirim & Correia, 2015). SABAS mood changes and feeling of pain when without the smartphone (Csibi et al., 2016) also used in Ward et al. (2017b).

Theory

Working Memory

Working memory is considered one of the core executive functions (Diamond, 2013). Executive functions are central properties of human cognitive functioning and enable people to think before acting, resist temptations, mentally play with ideas, and stay focused, amongst others (Diamond, 2013). Working memory requires holding information in mind and mentally working with information no longer perceptually present (Baddeley & Hitch, 1974; Smith & Jonides, 1999; Diamond, 2013). It is essential to point out that during the history of the science of memory and neurosciences, there has not been a complete unison (Chai, Hamid, & Abdullah, 2018). Throughout the years, several alternative models of working memory have also been proposed (e.g., Engle et al., 1999; Logie, 2011). The theory of the multi-component working memory theory introduced by Baddeley and Hitch (1974) is a well-known theory. There seems to be support for the goal-directed behavior involvement of working memory, and that there should be a retainment of information and manipulation to execute tasks successfully (Chai et al., 2018). Baddeley and Hitch's theory suggests that "working memory is a multi-component system that manipulates information storage for a greater and more complex cognitive utility" (Baddeley and Hitch, 1974). Working memory (WM) and short-term memory (STM) may still be used interchangeably, according to Baddeley (2012). He points out that the working memory-term emerged from an earlier concept of short-term memory (STM). Baddeley (2012) uses STM when referring to simple momentary storage of information, and WM about engaging storage and manipulation (Baddeley, 2012). This view of STM as a simple storage component and WM as more complex is somewhat supported by the working memory model suggested by Engle et al. (1999).

Measuring visuospatial working memory. The interchangeable use of terminology within the working memory further shows when setting out to measure the concepts. The design of the Spanboard test (Klingberg et al. 2002; Westerberg et al. 2004) is intended to measure visuospatial working memory by serial recall. The test is a forward span task, where subjects chronologically repeat first to last stimuli. According to Westerberg et al. (2004) the VSWM Spanboard test was adapted from Fry & Hale (1996). By using an anonymous stimulus such as the red circle, the test does not include verbal working memory. And due to the processing of the sequence one can argue the Spanboard task measures visuospatial working memory. There are however, some precautions to point out. The Spanboard task has similarities to the Corsi block-tapping test. This is a nonverbal test intended to measure visual STM (Berch et al., 1998; Miyake et al., 2001). Several blocks are displayed, and the task is to repeat the sequence that was displayed. This way the subjects must retain the sequence of stimuli and location of the stimuli. The number of tapped blocks will increase until a set standardized level. Another test hypothesized to measure visual STM, is the Wechsler nonverbal scale of ability, recognition (Wecshler & Naglieri, 2006). In this test subjects are to recall and point out the correct stimulus of a presented geometric pattern, choosing from five options. These differs in position, color and form.

Fluid intelligence

The theory of fluid and crystallized intelligence was first proposed by Cattell (1963), and together they are possible concepts of the general cognitive ability (***g***). Fluid intelligence (Gf) is to represent reasoning abilities and solving new problems. The crystallized intelligence on the other hand is to represent acquired skills and knowledge (Cattell 1963). Gf has similarities to WM regarding the ability to store, and manipulate information in a goal-directed manner (Ward et al., 2017a) and that it is dependent on available attentional resources (e.g., Engle et al. 1999; Halford et al. 2007). The Raven's Standard Progressive Matrices (SPM) was constructed to measure what they propose to be an component of ***g***, the eductive ability. This work is also based on Spearman's theory of general cognitive ability (Raven, Raven & Court, 2000). According to Raven, Raven and Court (2000) eductive ability is to able to forge new insights, perceive and identify relationships and the SPM was designed to cover a wide range of mental ability and thus, be sufficient for use among most people. The terms Gf by Cattell (1963) and eductive ability (Raven, Raven, & Court, 2000) are similar in many aspects, and despite their differences the terms are used interchangeably in the literature when using the SPM as a measure.

Measuring fluid intelligence. As mentioned above, the term fluid intelligence means the mental ability associated with abstract reasoning (Cattel, 1963, Bilker et al., 2012). One way of measuring this ability, is by abstract non-verbal multiple choice matrices like the Raven's Standard Progressive Matrices (SPM). This test is one of the most known and used measures is the Raven's Progressive Matrices (RPM) (Raven, Raven & Court, 2000). The RPM test battery consists of multiple tasks, and it is suggested they have a heavy demand on controlled attention (Engle et al., 1999). Even though the SPM is widely used, to perform the complete booklet of 60 items takes quite some time. Specially, since it is generally recommended not having a time limit (Raven, Raven and Court, 2000). Bilker et al. (2012) set out to reduce the time consumed administrating the SPM and still achieve reliable scores. They introduced the Nine-item abbreviated form of the Raven's Progressive Matrices, reducing administration time with approximately 75% (Bilker et al., 2012). However, there might be a training effect on tasks like these. Jaeggi et al. (2008) investigated whether training on working memory leads to transfer to Gf. Analyses of the training functions revealed that all four training groups improved in their performance on the working memory task comparably. Hayes, Petrov & Sederberg (2015) also reported increased fluid intelligence scores by training on such tasks.

Other Gf indicators can be found in the battery of RPM, by example, the Coloured Progressive Matrices (CPM), which is designed for children, the elderly, and people with learning disabilities, and the Advanced Progressive Matrices (AMP), which is designed for adults and adolescents with above-average intelligence. Performing these tests are similar to the SPM when inferring a missing figure in the matrix, choosing from a collection of alternatives. The person’s total score affords an index of intellectual capacity (Raven, Raven & Court, 2000). These are proposed to be utilized when in need for a more prominent differentiation at lower (CPM) and upper (APM) ends of distribution (Raven, Raven, & Court, 2000. The Wechsler nonverbal scale of ability is hypothesized to also be a measure of Gf (Wechsler & Naglieri, 2006). This is a matrix test, very similar to the CPM, where one figure is missing and the task is to select one figure from 5 alternatives. Also similar to the CPM, this test is applicable for those «whose performance on intelligence batteries might be compromised by standard verbal requirements» (Wechsler & Naglieri, 2006).

Current study

The current study intended to examine whether the smartphones’ presence effects scores on visuospatial working memory and fluid intelligence, and thereby demand cognitive resources when present. As mentioned above, Ward and colleagues (2017a) investigated how smartphones’ presence might be at the expense of some cognitive resources with limited capacity, and proposed the Brain Drain hypothesis. These cognitive resources are associated with executive functions such as working memory and fluid intelligence (e.g., Halford, Cowan, and Andrews 2007; Jaeggi et al. 2008). The field of working memory has laid the grounds for shaping the research questions of the current study. Test with a different research design, but the experiment design was inspired by Ward et al. (2017a), Some examples are the studies by Thornton et al. (2014) and Ward et al. (2017a), to the best of knowledge, no other studies have tested the Brain Drain hypothesis or replicated the study by Ward et al. (2017a) or Thornton et al. (2014).

For the current study, a within-subjects experiment was performed. A total of 40 students (mean age 23,74 years) were randomly selected to start with condition 1 (smartphone nearby) or start with condition two (smartphone in other room). Participants were instructed to either leave their smartphone before entering the testing room or told they could bring it inside. The Participants was given instructions on how to perform a visuospatial working memory (VSWM) test (Spanboard), and the Raven's Standard Progressive Matrices (SPM) and they would receive a questionnaire to measure possible subjective attachment or dependency to their smartphone. The term visuospatial working memory will be used to explain the measure of the Spanboard test. This is based on the terminology used by Klingberg et al. (2002) and Westerberg et al. (2004) when conducting the Spanboard test. Based on the findings from Thornton et al. (2014) and Ward et al. (2017a), the literature on a possible distracting effect on smartphone presence, there were room for some expectations concerning the current study's result. By testing the Brain Drain hypothesis, these three research questions will be answered:

I: Will the smartphone's presence significantly affect the scores on the visuospatial span test in a Norwegian sample of university students?

II: Will the smartphone's presence significantly affect the fluid intelligence scores in a Norwegian sample of university students?

III: Will attachment or dependency to one's own smartphone significantly affect the Brain Drain effect?

Method

Research Design

The main purpose of this study was to test the Brain Drain hypothesis (Ward et al., 2017a) in a sample of Norwegian students measuring visuospatial working memory, fluid intelligence and phone dependency and attachment. During trial the participants performed the visuospatial working memory span test Spanboard, the fluid intelligence test Raven's Standard Progressive Matrices (SPM), and the 13-Item Phone Attachment and Dependency Inventory (PADI) by Ward et al. (2017b). This study used a within-subjects design and the experiment was conducted with two different conditions; (1) solving half of the SPM and complete the Spanboard with their smartphones nearby, and (2) solving the other half of SPM and the Spanboard while their smartphone was in another room. All participants partook in both conditions, and were randomly assigned to one of two conditions at their first trial. During last trial, they would receive the other condition and at end of the last trial, participants carried out the PADI.

Pilot study. Six participants were recruited for a small pilot study, testing the Nine-item abbreviated form of the Raven's Standard Progressive Matrices by Bilker et al. (2012). The abbreviated form's two corresponding parts revealed nine out of nine correct scores by all six participants in both conditions. These identical results indicated that this version could be too effortless, and possibly a poor measure for this study. Therefore, it was decided to use the original form of Ravens Standard Progressive Matrices and split it in half to get a more demanding task.

Participants

For the main study, forty-seven Norwegian-speaking students were recruited from the Norwegian University of Science and Technology (NTNU). The data from four participants were excluded due to instruction errors, leading to testing the same condition. After the first testing, one participant withdrew from the study, and one participant did not show for the final testing. Another participant was asked to withdraw due to not being a student. (N = 40, average age 23,74 years, one missing, SD = 4.16), 25 women and 15 men (percentage 62,5% and 37,5%). This number is somewhat close to the national gender distribution of students in Norway for 2019, with 59,76 percent female students and 40,24 percent male students (Statistics Norway, 2020b). The main method for recruiting participants was through posters on message boards around the NTNU Dragvoll campus. Those interested in the study was encouraged to send an e-mail to the project manager to sign up and receive more information about the study. If asked for more specific information regarding the experiment, students were told they would get two tests concerning reasoning and working memory, lasting about 20 to 30 minutes altogether. Each participant was scheduled individually for the trials.

Experimental Conditions

One by one, the participants would attend the study and be randomly selected for one of two starting-conditions (phone nearby, or phone in the other room) upon arrival. Participants were asked two control questions before proceeding to the lab room; (1) to check that their cellphone was set to silent mode, including no vibration, (2) if they had a smartwatch and if this was set to silent mode with no vibration. These instructions were given to all participants and used as an opportunity to assign them one out of two conditions. While checking their cell phone, they would be invited to leave the phone with their belongings or bring it inside the lab. This moment also revealed whether or not the participant had a smartphone. Precautions were taken as not to bring too much attention around the smartphone and its' location. When entering the lab, the participant was told they would get two different tests, a working memory test on the computer, and a reasoning test with pen and paper. The participant was assigned to a table with a computer facing the wall. On their right side was a two-way mirror (Figure 1). In this position, they could see the experimenter sitting faced away behind them. Before the testing started, all participants were asked to read the Information and Consent paper (Appendix A). After reading, the participants were asked if they had any further questions about the experiment, and if they wanted to proceed. For the participants’ final trial, the same phrase was used upon arrival, and again checking their smartphone, participants would be encouraged to do the opposite condition from their first trial. A few participants needed persuasion for doing the opposite. They were either told they might need the smartphone at the end of the experiment, or leave it behind due to make sure no sounds or vibration could interfere with the trial. As compensation, all participants (n = 50) received a scratch lottery ticket (Million Flax, value 25 NOK) after finishing both experiment trials.

Figure 1. Image of the lab during the experiments

Figure 2. Image from the lab towards the entrance room

Spanboard. The visuospatial working memory test, Spanboard, was administered on a computer with the participant sitting approximately 50 cm from the screen. Memory stimuli in the form of red circles appeared one at a time, in a four by four grid (Figure 3) for 2250ms (Westerberg et al., 2004). After a sound indicated the round was over, the participant repeats the pattern by right-clicking with the computer mouse. The number of red circles would increase if the participant successfully completed two rounds within the same level. Termination of the test appeared when the participant failed to finish both rounds at one level correctly. The termination level indicated the participants' visuospatial working memory capacity. The test lasted between 5-10 minutes and had no time limit due to the test's self-terminating nature. During this VSWM test, several aspects of the participants' answers got registered. Such as how many clicks they used, the amount of correct series, test time, where their mistakes were made, and the maximum number of correct items. For further analysis, the total amount of correct items were used in this study.

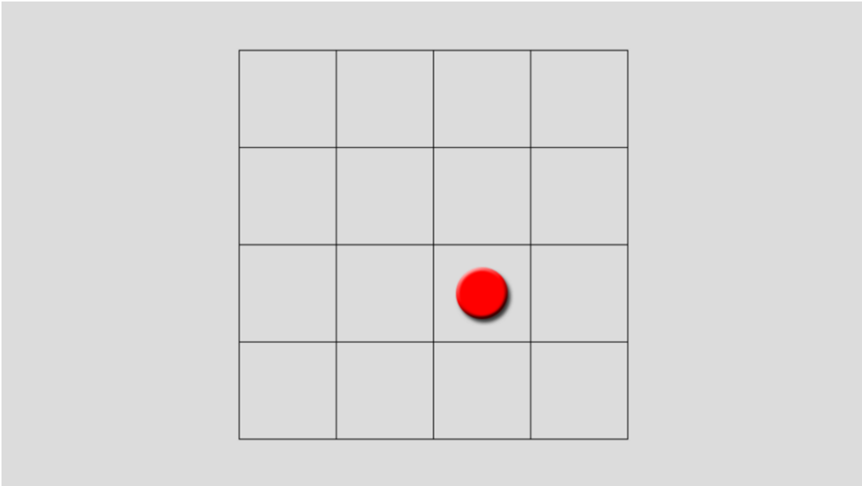

Figure 3. Screenshot of the VSVM task during test trial.

Ravens Standard Progressive Matrices (SPM). To measure possible impact on fluid intelligence, the SPM was assessed. The matrices consists of a booklet containing 60 items spread through five sets (A-E) following a different logic, and the items progressively becomes more demanding. The pen and paper version was administered and split in half by even and odd numbers. The first set consisted of set A-E with the odd-numbered items (A1, A3, A5, etc.); the second set consisted of set A-E with the even-numbered items (A2, A4, A6, etc.). The participants would choose amongst six pattern options, the one they reasoned to fit the missing section. Following the manual recommendations, participants had no time limit on this test (Raven, Raven & Court, 1998, 2000). The raw score for the number of correct matrices of each half was utilized for the analyzes.

13-Item Phone Attachment and Dependency Inventory. A Norwegian translation of the 13-Item Phone Attachment and Dependency Inventory used in Ward et al. (2017b) was formed by the project manager (Appendix B) and used to control for potential personal dependency and attachment to smartphones. This Norwegian translation has, to the best of knowledge, never been applied before this study. The inventory comprised of 13 items, and each item was measured by a 7-point Likert scale. Scoring 1 indicated “Strongly Disagree”, and scoring 7 indicated “Strongly Agree” (Appendix C). See Appendix D for the original English version. Control questions about age, gender, student status, and use of apps like Hold was also administered in the same questionnaire (Appendix C). The purpose of adding the question regarding the app Hold was to control for participants’ awareness of their smartphone’s possible distracting properties. The other questions only served as descriptive statistics about the sample and were not used in the analyzes. In the study by Ward et al. (2017a), they also included 10 other questions (e.g., phone use frequency, phone locations).

These were not included in this study due to time limitations to handle larger amounts of data. The results from the 13-item inventory and the Hold-question were further analyzed.

Procedure

All trials of the experiment were conducted in a lab at the Institute for Psychology at NTNU. The participants were told that the experiment investigated working memory, and that they would perform the tasks without any other participants present. Upon arrival, participants were instructed to leave their belongings (i.e., jacket, backpack) in a small room connected to the lab (Figure 2). No one could access this room without admittance on their ID-card. As part of not bringing too much focus on the participants' smartphone, they could leave their smartphone in their pocket or put it on the table next to them in condition 1 (phone nearby). If they put the phone on the table, they were encouraged to leave it face down due to the attention tests. Upon arrival, the participants were told the experiment would consist of one working memory test and a reasoning test. They would receive adequate information about the procedure and gave their informed consent to participate. The participants would perform the Spanboard test and solve the SPM.

The first test was Spanboard on the computer, and it was executed according to the protocol. For two participants, the test suddenly stopped during the trial, and the participants were asked if they wanted to restart the test. They were offered a break in case they needed to relax after the first round. Upon finishing Spanboard, participants were asked if they were ready to proceed to the next test. The pen and paper version of SPM was then administered according to the manual. The experimenter would explain the test and make sure the participant understood the test's concept before starting the test. At the end of the final trial, the participants received and conducted the inventory, this was the last procedure of the trial. The number of participants was satisfactory regarding the within-subject research design. All participants received a scratch lottery ticket (value 25 NOK) after they finished their last trial. Participants were encouraged to come back for the last trial at least one week (7 days) after their first trial. Informed consent was given before starting the tests, reassuring the participants they could withdraw at any time before, during, and after the trials, without giving a reason. Each participant received the scratch lottery ticket (Million Flax, value 25 NOK) for participating at the end of their second trial. Attached to the scratch lottery ticket was a small note with the project manager's e-mail address.

Anonymity and confidentiality

The data collected in this study was carefully handled by the project manager, and no other people had access to information about the participants or the results. Before data collection was initiated, the online checklist by the Norwegian Centre for Research Data (NSD) was used. According to this, the data collected in this study did not require an application to the NSD. This was also confirmed over their chat service when explaining the project more detailed. The participants' e-mail addresses were deleted after the first appointment was made, in agreement with guidelines from the NSD. The second appointment was therefore made at the end of the first trial.

Statistical analysis

All statistical analysis was performed with the SPSS 26.0 software package. Before testing the hypothesis and research questions of the study, the underlying assumption of a normally distributed sample for parametric analyses was examined (Field, 2013). Throughout the study, an alpha level 0.5 was used. The Shapiro-Wilk test was performed due to the methods’ suitability for small samples (<50) (Leard Statistics, 2020). The Shapiro-Wilk test showed that the data was not normally distributed for the score on the Spanboard task in condition 1; $p = .000$, the Spanboard task in condition 2; $p = .011$, SPM condition 1; $p = .021$, and SPM condition 2; $p = .007$. Testing the distribution of the data showed skewness, in both the Spanboard and SPM. Thus, the assumption of a normal distribution was violated (Field, 2013). Based on these results, a non-parametric test was deemed a better fit to analyze this sample. The Wilcoxon signed-rank test was conducted; this test is the non-parametric equivalent of paired-samples t-test and is suitable for repeated measures data (Field, 2013).

The goal of conducting the PADI was to control for moderation effects by participants’ possible dependency or attachment to their smartphones. Testing the reliability revealed the 13 questions had acceptable reliability, Chronbach’s $\alpha = .79$. Based on the violations of assumptions on both the SPM test and Spanboard test, performing a parametric analysis with all these variables combined would not be reasonable as there is no good non-parametric analysis equivalent to investigate moderation effects. It was decided to analyze all these data together with a non-parametric correlation. Due to the violation of normality, and the smaller sample size, the Kendall’s tau (τ) correlation analysis was considered appropriate to investigate these data further. (Field, 2013). The Kendall’s tau correlation coefficient τ is substantially smaller compared to the more known Spearman’s r_s and Pearson’s r (Field, 2013). The Spearman’s rho (r_s) correlation analysis was, therefore, calculated separately for the statistical significant correlations (τ) for its effect size properties (Field, 2013). According to Field (2013), correlation coefficients ±.1 can be considered a small effect, ±.3 a medium effect, and ±.5 a large effect. These values guided the interpretation of the correlation analyses.

Results

Descriptive Statistics

In total, 15 men and 25 women participated (*N* = 40) in the study. The average age was 23,74 years, one missing (*SD* = 4.16). The average time between the first and second measure was 8.62 days, ranging from 6 to 21 days. 14 out of 40 participants reported they use the app called Hold or similar apps.

Group Sample Characteristics

There was not found any significant difference between scores on the performance of the Spanboard task in any of the two conditions. The same results were obtained for the two conditions of the SPM task. There was no significant change in scores when performing the SPM task while the smartphone was in another room or performing the SPM task with the smartphone in near presence. For mean values and standard deviation scores, see Table 1. To investigate relationships between smartphone attachment and dependency with the test scores, the non-parametric Kendall's tau correlation was administered. For mean values and standard deviations of the inventory, see Table 2.

Spanboard. The Wilcoxon signed-rank test showed, for the Spanboard score with the smartphone nearby (*Mdn* = 7), that it was not significantly different from the score when the smartphone was in the other room (*Mdn* = 7) *z = .746*, *p* = .456*, r* = .13. The mean value of the Spanboard test indicates there were very small differences between condition 1 and condition 2 when it came to performance.

Raven's Standard Progressive Matrices. There was no significant change in scores when performing the SPM task while the smartphone was in another room (*Mdn* = 28) compared to performing the SPM task with the smartphone in near presence(*Mdn* = 27.5), *z = 1.13, p* = .256*, r* = .08. This is also reflected in the mean values of the participants' performance, showing slightly higher scores in condition 1, compared to scores in condition 2.

Table 1.

Mean values and standard deviations of the results from both conditions on the VSWM task and the SPM task. For both task, the raw scores was used.

Variable	Condition 1	Condition 2
VSWM	6.6	6.5
	(1.29)	(1.39)
SPM	27.45	27.15
	(1.78)	(1.88)

Note. SPM = Raven's Standard Progressive Matrices, VSWM = Spanboard test. Condition 1 = smartphone nearby. Condition 2 = smartphone in the other room. There are no maximum score for the VSWM task. The SPM task a score of 30 is maximum for each trial.

13-Item Phone Attachment and Dependency Inventory. A Kendall's tau correlation was administered to explore the relationship between scores on the Spanboard test, the SPM task, and the participants' subjective view on their smartphone attachment and dependency to analyze the inventory. This analysis revealed no statistically significant correlations between SPM condition 1 and any of the 13 questions in the inventory, and using the Hold app (Appendix E). The same results was showed for the Spanboard condition 2 and most items in Spanboard condition 1. However, there was a medium, negative correlation between Spanboard condition 1 and PADI question number 8, this was statistically significant, τ = -.330, 95% BCa CI [-.555, -.069], p = .013, with an effect size of r_s = -.391, p = .013.

When it comes to the SPM test, there was found a small, negative correlation between SPM condition 2 and PADI question number 1, which was statistically significant, τ = -.266, 95% BCa CI [-.463, -.058], p = .041, effect size r_s = -.336, p = .034 . There were a medium, negative correlation between SPM condition 2 and the PADI question number 8 which was statistically significant, τ = -.310, 95% BCa CI [-.534, -.057], p = .016, with an effect size r_s = -.470, p = .002. There was also a medium, negative correlation between SPM condition 2 and the PADI question number 12, this was statistically significant, τ = -.383, 95% BCa CI [-.591, -.133], p = .003, with an effect size r_s = -.378, p = .016. Regarding the question about using apps like Hold and similar, the Kendall's tau correlation revealed no statistically significant correlations (Appendix E).

Table 2.

Mean value and standard deviation of the 13-Item Phone Attachment and Dependency Inventory, answered by a 7-point Likert scale.

	Question number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
M	5.23	4.22	4.50	5.13	4.65	4.53	5.02	2.83	3.63	5.68	3.28	2.75	4.68
SD	1.37	1.37	1.26	1.62	1.62	1.63	1.79	1.88	1.98	1.25	1.52	1.89	1.46

Discussion

This study set out to test the Brain Drain hypothesis by Ward et al. (2017a), by measuring if it had an effect on visuospatial memory and fluid intelligence tasks. The Brain Drain hypothesis suggests; "the mere presence of one's own smartphone may occupy limited-capacity cognitive resources and thereby leave fewer resources available for other tasks and undercut cognitive performance" (Ward et al., 2017a). The experimental design and measures were inspired by their study. In the current study potential cognitive disturbing effects was examined using measures of the concepts of fluid intelligence and visuospatial working memory. This was achieved by using the whole SPM, testing visuospatial working memory, and the PADI. To the best of knowledge, there are no more than two studies examining whether the presence of a cell phone (Thornton et al., 2014), or smartphone Ward et al. (2017a) can have disturbing properties regarding attention and task performance.

Group Sample Characteristics

When it comes to the group samples characteristics, there were no significant differences between the two test conditions. This appears from the main scores (Table 1.) and the non-significant results of the Wilcoxon signed-rank test.

Research question I: Will the smartphone's presence significantly affect the scores on the visuospatial memory in a Norwegian sample of university students?

Regarding this research question, the Wilcoxon signed-rank statistical analysis revealed that the smartphone's presence did not affect the visuospatial memory as measured by Spanboard. Due to no significant difference detected between the scores in Spanboard regarding the two different conditions. Therefore, there is not support for the Brain Drain hypothesis. As mentioned above, there have been an interchangeable use of terminology regarding working memory and short-term memory. In the majority working memory literature presented in this study, has categorized this measure to better fit the visual short-term memory terminology (Berch et al., 1998; Miyake, 2001; Baddeley, 2012). This is due to the differentiation between what cognitive resources theorized to be active during tests like Spanboard and Corsi block-tapped test. The simpler cognitive challenges in the Spanboard may explain why there was no significant difference between the two conditions in this study when comparing to the results in the study by Ward et al. (2017a).

Research question II: Will the smartphone's presence significantly affect the fluid intelligence scores in a Norwegian sample of university students?

The results from the study revealed that the smartphone did not have an significant effect on scores on fluid intelligence in this sample. One reason for this could be that the original form of Ravens Standard Progressive Matrices was split it in half to get a more difficult task rather than an the abbreviated form to fit the within-subejcts design. This is different from the ten-item form used by Ward et al. (2017a). Therefore, the choice fell on Bilker et al. (2012) more tested short version. When this version seemed too effortless, it was decided to use the original 60-item test and split it in half. Hence, the SPM is not to be interpreted directly as a measure of fluid intelligence, but rather how the WMC was functioning during the tests. This could possibly create an interpretation issue when it comes to the results of the SPM, the results and it cannot be directly compared to the results for finishing the complete 60 items at once (Raven, Raven, Court, 1998). Also the main scores reveals that the participants scored quite high, 27 out 30 possible in both trials. This can be an indication that the sample has an above-average intelligence, and that the Advanced Progressive Matrices would be a better measure for this sample. Efforts were made to obtain this version, but due to financial restrictions it was not applicable. There has been shown some training effects for the SPM (Jaeggi et al., 2008), as such it is possible that participants had an effect from their first trial. It is also possible that some of them has encountered similar matrices in the past. It is also pointed about by Raven, Raven and Court (2000) there has been an increase in the eductive ability levels over the years. Some participants seemed quite motivated and interested in their own score on these tests, which could be a confounding variable. It is possible this served as an extra motivation, making these participants less receptable to the stimuli from their smartphone.

Research question III: Will attachment or dependency to one's own smartphone significantly affect the Brain Drain effect?

Due to violation of the normality assumption in the cognitive measures Spanboard and SPM the effect of the PADI could not be assessed as intended. Instead a non-parametric correlation analysis was used to reveal any relationships between the different measures used in this study. This analysis partially answers the research question, by showing significant correlations between the following measures: SPM in condition 2 showed a small, negative correlation with the statement (1) of having trouble getting though a normal day without the smartphone. SPM condition 2 also had a medium, negative correlation with the statement (8) indicating feeling lonely when the smartphone does not ring or vibrate for a few hours. Further there was a significant medium, negative relationship between the SPM condition 2 and statement (12) regarding experiencing it as painful to give up the phone for a day. Condition 2 was the condition with the smartphone in the other room, and all these statements indicates some sort of negative experience or emotion when encountered with situations where the smartphone is not used as normal. For the Spanboard task condition 1, only one correlation was significant. It showed a medium, negative relation to statement (8) indicating feeling lonely when the smartphone does not ring or vibrate for a few hours.

The inventory explored the participants relationship to their smartphone, thus far this inventory has only been tested on larger sample sizes (Ward et al., 2017a). The 13-Item Phone Attachment and Dependency Inventory could be more investigative when it comes to why people choose to use their smartphone as they do, and not only explore if they experience positive or negative emotions in different situations of smartphone use. Today, many rely on their smartphones to do their work as it is expected to be reachable at almost all times. Receiving and answering e-mails can be done anywhere with wi-fi or mobile internet. For some this is likely to be a forced dependency or attachment to the smartphone due to social or professional norms arisen alongside the development of smart technology. The questions not included in this study from Ward et al. (2017a) explored details concerning the frequency of use, often the questions not asked can help reveal perspective to the results and how to improve the research. In hindsight, not including these exploring questions in the current study to save participants some extra minutes on the final trial seems like a poor choice. Nonetheless it was weighed back and forth regarding the time required for each participant, times two on the cognitive tasks. Also, during the recruitment, many people asked how long it would take. Some spent a lot of time (30 minutes or more) on the SPM alone, as was allowed. This consideration was also part of the administration time for the experiments available, needing at least 34 participants to reach a sufficient statistical power. Another factor to keep in mind is that the questionnaire at the end may have given the participant a feeling of deceit and therefore either make them respond the way they think they are supposed to or not answer as they truly feel. Both dependency and addiction to smartphones has been investigated with significant findings ( ). Although there are sone severe cases of smartphone addiction, these results are seemingly limited to those with proneness to additive behavior (). Findings of comorbidity between smartphone addiction, depression () and other mental illnesses () are important considerations to take when interpreting findings like these

Research design

Within-subjects design may have cause some confusions for participants on the second trial. Several of the participants did not follow the request to leave or bring their smart phone, which led to challenging randomization of conditions. It all worked out well, though in hindsight this could be solved differently in a similar situation. Also, some participants might have felt a responsibility to perform well, especially since the project manager was sitting behind them during trials. The fact that they signed up for an attention study might have primed them or made them extra aware of focusing. The within-subjects research design combined with the measures could have had an effect on the results when compared to the findings from Ward et al. (2017a). When it comes to how the study was presented as an attention study, it is not unlikely that some of the participants were drawn towards a study focusing on attention, as they could have an interest in their own performance. It is also likely that some participated in testing their attention performance and thus were motivated to perform as well as possible. In the information given, participants were told to relax and solve the tasks with their best effort. Asking for their best effort could boost those prone to excel in the study and influence the study's results.

Several participants had knowledge of and used apps like Hold, this suggests an overall consciousness around the distracting elements of the smartphone. The number of participants using that app in this study (n=14) shows it is not an unusual app to have. On the other hand, receiving points while not using one's own smartphone might be a big enough motivation for many students. Further research on adults should, therefore, investigate this assumption. The participants was offered compensation (scratch lottery ticket), although, this is a small reward but still one cannot assume it had no effect. Participants showed an interest in what the study was really investigating. However, the inventory about smartphone use was surprising for most participants, and only one participant guessed it had something to do with the smartphone's location. Some participants reported they were so focused on participating that they did not care too much about their surroundings, this could possibly be due to unfamiliar setting and tasks. Being in a room alone with the instructor could have had an impact on how the participants acted and performed, one advantage of the study was the laboratory testing, hence, each participant performed the tests under the same conditions.

According to the results, on average, the participants performed slightly better when the smartphone was close by. This can be due to that they are used to having their smartphone close by when studying. It can also be due to anxiety when the smartphone is not near them, since these participants are considered digital natives. One possible explanation is that they are better at focusing when they really want to and have to. On the other hand, the effect of wanting to succeed in the tests and please the instructor, the bias of performing, can also explain the near identical results. Possibly all these explanations have had an effect in this study regarding the unclear results. A sample size of 40 when using a within-subjects design should give enough statistical power, except for the questionnaire which usually requires a minimum of 200 participants to achieve robust statistical power.

As indicated above, the long-term effect of using smartphones and such digital devices is still debated, and research findings are not conclusive (Wilmer et al.; Mills, 2014; Orben & Przybylski, 2019).

Limitations of this study

In the current study there are multiple limitations. One of these are the measures used. Using measures inspired by the experiment done by Ward et al. (2017a), the concepts are and due to natural limitations with a master's thesis (e.g., financial resources, time limitations), an exact replication was not achievable. However, testing the hypothesis measuring the similar concepts was possible. The consent paper could favorably explain more about the tests conducted (Appendix A), what the tests measure and how it might affect (or not affect) the participant. To get a better grasp on possible confounding variables questions regarding frequency use of smartphone could have been included in the survey. This could possibly have contributed to explain more of the complex relations of behavior and smartphone use. In hindsight, this would not necessarily have taken too much time for the participants. When it comes to the research design, one limitation is the assigning of conditions. This was challenging du to balancing the knowledge participants had about the true hypothesis, and to keep the tests as unbiased as possible at the same time. It is possible that this made several of the participants to not follow the location request for their smart phone. The within-subjects design is also one limitation, and possible not a good fit for the measure of SPM combined with a shorter time span in between trials. This is due to the possibility of learning the way of solving the SPM after one trial. The Norwegian translation of the PADI questionnaire is also one limitation, since it has not been used before and therefore, one cannot be sure to what extent this is a good measure for smartphone dependency and attachment.

The Corsi block-tapping test has some similar properties as the Spanboard test regarding their setup and execution, it is likely they measure the same concept.

The fact that this is not a replication study, but merely inspired and experimental similar has it limitations as to making generalizations from the results.

Conclusions and Future Research

The intention of this study was to examine if smartphones affect our cognitive functioning, by testing the Brain Drain hypothesis. Arguably, testing the same hypothesis with a different research design and measure is a strength considering possible new insights to the existing findings. Arguably, an equally important standard to set for scientific research is building a valid and reliable body of data and in that way contribute significantly to the scientific field of psychology. Some issues has been reported as the replications crisis. Pointing out that by rewarding mostly new and original research in the social science one might not get a solid foundation of replicated results. This is largely based on the fact that social sciences use measurements and constructs that are somewhat fluid and therefore need to be tested and replicated. By encouraging an atmosphere for taking upon the work of replication, a balance of originality and replication could bring the field even further and in more unison. Considering this, the current study showed that a within-subjects design and the Spanboard measure might not be a good fit for this hypothesis. The potential implications afforded by the earlier findings when testing the Brain Drain hypothesis, might give new insights to how we understand our own mind. This study has brought a small, but valuable contribution to the investigation of disturbing effects of smartphone presence.

Future research could look more at the differences between effects when children use smartphones and compare to adolescent or adult use, using longitudinal studies. Many of the concerns of smartphone use are pointed at the unknown effect on children's development. Unison and reliable research results regarding smartphone use can guide the development of smartphone technology, set limits for what is sustainable smartphone use, from childhood throughout adulthood. Also, it might help recognize what behavior to be concerned about and when and how to act on problematic smartphone behavior. The digitalization has so many helpful aspects, and used right it is a tool with no opponents. This "monopoly" is , therefore, important to balance as not to risk the worst outcomes. Other future research could examine questionnaires used in measuring smartphone dependency and maybe interviewing people in based on their attachment to the smartphone, to better understand what lies behind their use. The questionnaires mentioned in this study all asks questions on a more "superstitious" level, and seemingly does not ask questions about the society people live in and how this might affect their smartphone use. Adolescents, children, adults, and older people all have different motivation to use smartphones, and some of reasons might in common. This could possibly be a source of understanding the use of smartphone on broader level. Perhaps a wider focus on questions revealing whether people use the smartphone due to norms and social habits would give a valuable insight to smartphone usage.

There is a large focus on possible negative impacts from smartphones, SNS and gaming platforms on our mental and physical wellbeing. However, humans are flexible and adaptable to new challenges in an astonishing way, and this topic need to get more attention and research. Most people are not likely to have problems with severe addictions, although some dependency is likely due to the structure of today's societies.

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Appendix A Written informed consent

Informasjon om studien og samtykke

Informasjon om studien

Denne studien er del av en masteroppgave som omhandler oppmerksomhet. Mer presist sees det på flere aspekter ved arbeidsminnet ved å bruke to forskjellige tester. I hverdagen er det mange ting som krever vår oppmerksomhet og det å holde fokus avhenger av flere ting, slik som for eksempel energinivå, interesse, forstyrrelser og motivasjon.
Målet med masteroppgaven er å kunne bidra til vitenskapelig kunnskap om aspektene ved arbeidsminnet. I dette eksperimentet trenger du bare slappe av og løse oppgavene etter beste evne. Det innebærer ingen fysiske ubehag ved deltakelse, og det er ingen kjente negative bivirkninger ved å ta disse testene. Siden datainnsamlingen pågår over en lengre tidsperiode settes det stor pris på om du ikke deler informasjon om testene og studiet med andre. Dette vil bidra til at målingene blir mer nøyaktige og å gi et sikrere resultat av funnene i studien.

Samtykke og personopplysninger

Det er helt frivillig å delta og du kan når som helst trekke deg fra denne studien, uten å oppgi grunn. Dette kan du gjøre muntlig i løpet av eksperimentet, eller du kan sende en e-post (til margrers@stud.ntnu.no) dersom du vil trekke deg i ettertid. For å oppbevare minst mulig personidentifiserende opplysninger vil din deltakelse være tilstrekkelig for å gi ditt samtykke. NB! Personopplysningene behandles konfidensielt og innsamlet data kan ikke kobles tilbake til deg som person.

Takk for din deltakelse!

NTNU
Kunnskap for en bedre verden

Appendix B Translation and overview of the 13-item Phone Attachment and Dependency Inventory

Overview of the 13-Item Phone Attachment and Dependency Inventory questions, numbering and Norwegian translation equivalent.

English questions	Item number	Norwegian Translation
I would have trouble getting through a normal day without my cell phone	1	Det ville vært vanskelig å komme gjennom en vanlig dag uten mobilen min
Using my cell phone makes me feel happy	2	Det å bruke mobilen gjør meg glad
I feel excited when I have a new message or notification	3	Jeg blir glad/ opprømt når jeg får en ny melding eller varsling
If I forgot to bring my cell phone with me, I would feel anxious	4	Hvis jeg glemmer å ta med mobilen min, blir jeg engstelig
It drives me crazy when my cell phone runs out of battery	5	Jeg blir veldig frustrert når mobilen går tom for strøm
I am upset and annoyed when I find I do not have reception on my cell phone	6	Jeg blir irritert når jeg ikke har dekning på mobilen
I feel impatient when the Internet connection speed on my cell phone is slow	7	Jeg blir utålmodig når hastigheten på nettet er lav/treig
I feel lonely when my cell phone does not ring or vibrate for several hours	8	Jeg blir ensom når mobilen ikke ringer eller vibrerer på flere timer
I feel like I could not live without my cell phone	9	Jeg føler jeg ikke kan leve uten mobilen min
I become less attentive to my surroundings when I'm using my cell phone	10	Jeg blir mindre oppmerksom på omgivelsene når jeg bruker mobilen min
Using my cell phone relieves me of my stress	11	Ved å bruke mobilen blir jeg mindre stresset
It would be painful for me to give up my cell phone for a day	12	Det ville vært smertefullt for meg å gi opp mobilen for en dag
I find it tough to focus when my cell phone is nearby	13	Jeg syns det er vanskelig å fokusere når mobilen min er i nærheten

Appendix C 13-Item Phone Attachment and Dependency Inventory, Norwegian version

Mobilbruk i hverdagen

Helt til slutt får du noen spørsmål rundt bruk av smarttelefon i hverdagen. Om du har spørsmål eller noe er uklart underveis er det bare å spørre. Det settes pris på at du svarer så presist og ærlig som mulig.
Det er frivillig å delta, og du kan når som helst trekke tilbake ditt samtykke uten å oppgi grunn. Dette kan du gjøre ved å si fra i løpet av gjennomføringen eller ved å ta kontakt via e-post (til margrers@stud.ntnu.no) i etterkant.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Personopplysninger som samles inn behandles konfidensielt og i samsvar med personvernregelverket. Alle svar er anonyme og det vil ikke bli offentliggjort data som kan identifisere den enkelte deltaker. Kun studieansvarlig har tilgang til e-postadresse eller telefonnummer frem til datainnsamlingen er avsluttet, senest 01.04.2020.

Tusen takk for din deltakelse!

NTNU
Kunnskap for en bedre verden

Nedenfor får du presentert flere påstander og spørsmål angående bruk av smarttelefon. Vennligst kryss av det svaret som passer best for deg.

	Veldig uenig	Ganske uenig	Litt uenig	Nøytral	Litt enig	Ganske enig	Veldig enig
Det ville vært vanskelig å komme gjennom en vanlig dag uten mobilen min	☐	☐	☐	☐	☐	☐	☐
Det å bruke mobilen gjør meg glad	☐	☐	☐	☐	☐	☐	☐
Jeg blir glad/ opprømt når jeg får en ny melding eller varsling	☐	☐	☐	☐	☐	☐	☐
Hvis jeg glemmer å ta med mobilen min, blir jeg engstelig	☐	☐	☐	☐	☐	☐	☐
Jeg blir veldig frustrert når mobilen går tom for strøm	☐	☐	☐	☐	☐	☐	☐
Jeg blir irritert når jeg ikke har dekning på mobilen	☐	☐	☐	☐	☐	☐	☐
Jeg blir utålmodig når hastigheten på nettet er lav/treig	☐	☐	☐	☐	☐	☐	☐
Jeg blir ensom når mobilen ikke ringer eller vibrerer på flere timer	☐	☐	☐	☐	☐	☐	☐
Jeg føler jeg ikke kan leve uten mobilen min	☐	☐	☐	☐	☐	☐	☐

	Veldig uenig	Ganske uenig	Litt uenig	Nøytral	Litt enig	Ganske enig	Veldig enig
Jeg blir mindre oppmerksom på omgivelsene når jeg bruker mobilen min	☐	☐	☐	☐	☐	☐	☐
Ved å bruke mobilen blir jeg mindre stresset	☐	☐	☐	☐	☐	☐	☐
Det ville vært smertefullt for meg å gi opp mobilen for en dag	☐	☐	☐	☐	☐	☐	☐
Jeg syns det er vanskelig å fokusere når mobilen min er i nærheten	☐	☐	☐	☐	☐	☐	☐

Alder: Kjønn:

Heltidsstudent ☐ Deltidsstudent ☐ Ferdig utdannet ☐

Bruker du en smarttelefon som din faste mobil?: Ja ☐ Nei ☐

Bruker du apper som Hold eller lignende? Ja ☐ Nei ☐

Hvis ja, var appen i bruk under deltakelsen? Ja ☐ Nei ☐

Appendix D The 13-Item Phone Dependency and Attachment Inventory, English version

Web Appendix Table 1. Factor Analysis of 13-Item Phone Attachment and Dependence Inventory.

	Factor		
	1	2	3
I would have trouble getting through a normal day without my cell phone	.85		
It would be painful for me to give up my cell phone for a day	.81		
I feel like I could not live without my cell phone	.79		
If I forgot to bring my cell phone with me, I would feel anxious	.75		
It drives me crazy when my cell phone runs out of battery	.66		
I am upset and annoyed when I find I do not have reception on my cell phone	.64		
I feel impatient when the Internet connection speed on my cell phone is slow	.52		.43
I feel lonely when my cell phone does not ring or vibrate for several hours		.73	
Using my cell phone relieves me of my stress		.71	
I feel excited when I have a new message or notification		.70	
Using my cell phone makes me feel happy		.68	
I find it tough to focus whenever my cell phone is nearby		.64	
I become less attentive to my surroundings when I’m using my cell phone			.90

Appendix E Kendall's tau correlation matrix

Kendall's tau correlation matrix, all analyzed variables included.

		SPM1	*SPM2*	*VSWM1*	*VSWM2*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*Q12*	*Q13*	*Hold*	
1	*SPM1*	1	**.379****	**-.266***	**.253***	**.346****	-.044	-.041	-.016	.028	.159	.169	.100	-.214	.000	.086	-.035	-.227	-.031	1
2	*SPM2*		1	**.346****	-.033	**-.266***	-.069	-.030	-.141	-.065	.056	.012	**-.310***	-.081	.210	-.183	**-383****	.212	.117	2
3	*VSWM1*			1	**.519****	-.142	.019	.061	-.168	-.230	-.046	-.104	**-.330***	-.134	-.083	-.194	-.183	.056	-.090	3
4	*VSWM2*				1	.054	.008	-.071	-.124	-.005	.027	.169	-.076	-.054	.079	-.086	-.107	.070	-.027	4
5	*Q1*					1	**.349****	.021	**.377****	**.369****	.122	**.258***	**.359****	.232	-.032	**.372****	**.527****	-.057	.184	5
6	*Q2*						1	.214	.038	.003	.098	.058	.100	.236	-.126	**.424****	**.412****	-.085	.233	6
7	*Q3*							1	.134	.018	-.095	-.099	.166	-.039	-.118	.164	.126	-.059	.239	7
8	*Q4*								1	**.255***	.060	.158	**.281***	.165	.172	**.302***	**.378****	.190	.248	8
9	*Q5*									1	**.365****	**.318***	**.307***	.228	.178	**.319***	**.333***	.163	.127	9
10	*Q6*										1	**.462****	.032	**.323****	.123	.040	.183	.138	.114	10
11	*Q7*											1	.199	**.252***	**.333***	-.052	.116	.082	.128	11
12	*Q8*												1	**.264***	-.105	.205	**.382****	.029	-.061	12
13	*Q9*													1	.053	**.298***	**.454****	.099	.107	13
14	*Q10*														1	.007	-.012	**.290***	.237	14
15	*Q11*															1	**.515****	.106	.221	15
16	*Q12*																1	.017	.046	16
17	*Q13*																	1	.022	17
18	*Hold*																		1	18

Note. SPM1= SPM test with the smartphone nearby, SPM2= SPM with the smartphone in the other room. VSWM1= Spanboard test with the smartphone nearby, VSWM2= Spanboard test with the smartphone in the other room.

Q1-Q13 = the invenory questions as ranked in Appendix B

** significant at .01 level

* significant at .05 level