University of Basel
Faculty of Psychology

Master's thesis presented to the Department of Psychology of the University of Basel for the degree of Master of Science in Psychology

Brain Drain Revisited: Smartphone Presence and its Effects on Cognitive Performance in the Light of Smartphone Attachment and Fear of Missing Out

Author: Quanbrough Jasmine

Immatriculation number: 12-105-839

Correspondence email: jasmine.quanbrough@stud.unibas.ch

Examiner: Prof. Dr. Opwis Klaus

Supervisor: Dr. Iten Glena

Division in which this work was completed: Center for Cognitive Psychology and Methodology

Submission date: 15. October 2018

Abstract

Recent research has found mere smartphone presence to reduce available working memory capacity and to therefore have negative effects on cognitive performance. With the aim of replicating this finding, a between-subject design experiment was conducted (*n* = 99). Participants were randomly assigned to one of two conditions – smartphone present or smartphone absent. To measure cognitive performance across conditions, participants completed the Ospan task. Further investigations included participants' subjective feeling of having been distracted by their smartphones throughout the task and the effects of smartphone attachment and fear of missing out on the relationship between smartphone presence and cognitive performance. Results showed that smartphone presence did impair participants' cognitive performance. Furthermore, participants across conditions did not assume their smartphones had an influence on them, independent of whether they were affected or not. However, analyses on smartphone attachment and fear of missing out failed to explain any mediating or moderating effects on the relationship between smartphone presence and cognitive performance. In conclusion, people ought to be aware of the distracting influence their smartphones' presence has on them while completing cognitively demanding tasks, even when considering themselves not to be at risk of being affected.

Keywords: smartphone presence, working memory capacity

Brain Drain Revisited: Smartphone Presence and its Effects on Cognitive Performance in the Light of Smartphone Attachment and Fear of Missing Out

What Ward, Duke, Gneezy, and Bos (2017) refer to as “Brain Drain” is the subject of this paper. The authors claim that people perform cognitively worse when in presence of their smartphones due to cognitive resources being “drained” by the necessity to suppress distracting thoughts caused thereby. Thornton, Faires, Robbins, and Rollins (2014) also reported that their participants were distracted by the mere presence of their smartphones. Both studies have in common that they require participants to complete a cognitively demanding task while in presence of their smartphones. Research on this topic is however scarce although very important, since many people complete tasks in presence of their smartphones. We strive to provide further evidence of the effects of smartphones’ mere presence. Furthermore, said research considered few potential moderating or mediating influences on the relationship between smartphone presence and cognitive performance. Therefore, we investigate constructs that may influence the relationship in a mediating or moderating manner.

Theoretical Background

To date, several studies have been conducted examining how the use of cell phones and smartphones affects the completion of focal tasks. For instance, the use of cell phones while driving results in distracted driving (Caird, Willness, Steel, & Scialfa, 2008). Caird et al. (2008) conducted a meta-analysis and found that while talking on the phone, even hands-free, reaction time to events and stimuli is increased. Furthermore, Hyman, Boss, Wise, McKenzie, and Caggiano (2010) demonstrated effects of divided attention by conducting experiments comparing the behavior of cell phone users, MP3 player users and participants without any electronic devices. Participants who used their cell phones walked more slowly, changed directions more frequently and were less likely to acknowledge other people. Moreover, the authors found that cell phone users were less likely to notice unusual activity, specifically a unicycling clown.

With the age of smartphones new fields of research emerged and new findings were presented. For example, the use of smartphones impairs learning, as has been found in several studies. Froese et al. (2010), for instance, found that interacting with mobile devices, specifically with social media, while learning new material impairs the learning outcomes. Students' performance decreased by nearly 30% when answering questions about a presentation they had previously listened to and texted throughout. Duncan, Hoekstra, and Wilcox (2012) reported a significant negative correlation between in-class cell phone use and students' final grades.

As it seems, people have difficulties when interacting with their devices and simultaneously paying attention to cognitively demanding tasks. As a result, they are often not able to reach their full potential due to their habits of multitasking (Duncan et al., 2012). However, the term multitasking is assumed to be potentially misleading and needs clarification. Salvucci, Taatgen, and Borst (2009) refer to the Multitasking Continuum when presenting forms of multitasking and classify these in terms of the time spent on one task before switching to another. Concurrent multitasking on one end of the continuum refers to tasks being performed virtually at the same time, with very little time being spent on one task before switching to another. On the other end of the continuum is sequential multitasking which involves spending lots of time on a task before switching to another. It is assumed that cognitive resources are required to perform the actual switching of tasks which in turn reduces available cognitive capacity needed for the tasks in focus.

Further research reports effects of smartphone notifications on task performance. Stothart, Mitchum, and Yehnert (2015) discovered that students' cognitive performance was reduced upon receiving notifications on their smartphones, without actively interacting with their devices. Performance is also impaired when being distracted by a cell phone ringing, as reported by End, Worthman, Mathews, and Wetterau (2010). Students who were interrupted by ringing cell phones while watching a video performed significantly worse on multiple-choice tests on the video material than students in the control group.

Ward et al. (2017) suggest that the increasing integration of smartphones into daily life lays the foundation for automatic attention diversion by frequently being relevant to their owner's goals, thus personally significant. There is even physiological evidence for this suggestion. Clayton, Leshner, and Almond (2015) found that people's heart rate and blood pressure increased when unable to answer their phones while completing cognitive tests. Their participants also reported increased anxiety and unpleasantness. The authors agree with Cheever, Rosen, Carrier, and Chavez (2014) that this phenomenon is related to the finding that physical and emotional attachments people have developed with their smartphones have increased. In a similar vein, Roye, Jacobsen, and Schröger (2007) were able to demonstrate that ringtones from one's own phone activate the same automatic attention system that responds to the sound of one's own name due to similar personal significance.

As smartphones have become our constant companions and are present in many day-to-day situations, it seems important to know about any effects they have on us just by being present. This brings us to the question of how the mere presence of our smartphones influences cognitive performance.

Smartphone Presence

To date, not much research has been conducted to examine the effects of the mere presence of people's smartphones on their lives. Fairly recent research has demonstrated the distracting effects smartphones' mere presence has on social interactions. According to Thornton, et al. (2014), smartphones may have negative consequences for immediate social interactions as their presence may serve as a constant reminder of the broader social network that is potentially available. Przybylski and Weinstein (2013) found that smartphone presence reduced perceived closeness, trust, empathy and understanding between conversation partners, especially if they were discussing personally meaningful topics. They also discovered that this might happen subconsciously, leaving people unaware of the effects their smartphones have on their relationships. This finding is quite alarming given the fact that smartphones are often present during conversations.

As smartphones' presence apparently affects people psychologically, it is reasonable to investigate the effects on cognitively demanding tasks. We contribute to the research on this subject by exploring the effects of smartphones' mere presence on cognitive performance and complement research by Ward et al. (2017) and Thornton et al. (2014).

Working Memory Capacity and Cognitive Performance

Though constantly surrounded by stimuli and potentially meaningful events, individuals are limited in processing these stimuli by their cognitive capacity. This restriction allows individuals to absorb and process information only in small amounts at any given time (Craik & Lockhart, 1972). Therefore, individuals must allocate their limited attentional resources carefully in order to gain the best possible knowledge of the events going on.

Working memory processes are thought to be involved in the allocation of attention, as Roberts, Hager and Heron (1994) found in their study involving eye movements away from attention-drawing stimuli. Participants were instructed to ignore distracting and attention-grabbing stimuli, suppress thoughts thereto and focus on a task. The authors found a correlation between participants' success in ignoring distracting stimuli and their working memory capacity. De Fockert, Rees, Frith, and Lavie (2001) were able to further demonstrate the relationship by combining behavioral experiments with neuroimaging methods.

Some findings suggest that people's attention can be influenced by personal relevance. Conway, Cohen, and Bunting (2001) replicated Moray's (1959) study and demonstrated this which is widely known as the cocktail party phenomenon. In a noisy room with several discussions going on around them, people are able to follow a specific discussion in which they previously heard their name being mentioned. In the midst of a lot of noise, personally relevant information can be detected quite easily.

According to Ward et al. (2017), performance on cognitive tasks declines as working memory capacity is used to inhibit distracting thoughts or to control attention diversion. In the context of completing demanding cognitive tasks with smartphones present, smartphones could be a factor in distracting people's thoughts away from the focal task. Working memory capacity is used to inhibit these thoughts and focus on the task at hand. This may decrease performance as the working memory capacity used for inhibiting distracting thoughts and controlling attention cannot be dedicated to the focal task. By applying a working memory span test, working memory capacity available for the main task can be indirectly measured. We expect performance, as a function of available working memory capacity, to be decreased with participants' smartphones being present in comparison with participants' cognitive performance in their smartphones' absence.

H1: Available working memory capacity, measured using the Ospan task, is lower for participants whose smartphones are merely present than for participants whose smartphones are absent.

Subjective Distraction

If the mere presence of people's smartphones does affect their cognitive performance, it is interesting to examine whether they are aware of the distraction. This question is important as a large number of people have their smartphones with them at all times, even in situations which require their complete attention. Not being aware of any distractions their smartphones have on them may have important consequences and need to be addressed.

Lesch and Hancock (2004) were able to show that while drivers were in fact distracted by using their cell phones, they were not necessarily aware of the distracting effects resulting in decreased performance. Similarly, Ward et al. (2017) had participants rate the perceived influence of smartphone presence after completing working memory span tests. Across conditions, the participants indicated that the location of their smartphones did not affect their performance in any way, neither positively nor negatively. For the participants in the smartphone present condition there was a discrepancy between perceived influence and actual performance. The presence of their smartphones did in fact affect their performance without them realizing it. This finding is particularly important for the present study as the effects of mere smartphone presence and, on a meta level, the retrospective realization of these effects are examined.

H2: Participants' average level of awareness of any distracting effects their smartphones' presence has on their cognitive performance does not differ between conditions.

Smartphone Attachment

With smartphones being so important to people's everyday lives, it is relevant to address the extent to which people are attached to their smartphones and the effects thereof on their cognitive performance. Clayton et al. (2015) demonstrated smartphone attachment on several levels including the physiological, describing smartphone attachment as an extension of one's self. When unable to answer their ringing smartphones, their participants' heart rate, blood pressure and self-reported feelings of anxiety and unpleasantness increased.

Ward et al. (2017) found that the extent to which people are distracted by their smartphones varies according to the personal relevance thereof. Participants more strongly attached to their smartphones performed worse than participants less attached. Therefore, smartphone attachment seems to play a moderating role in the relationship between smartphone presence and available cognitive capacity, the latter reduced by smartphone presence and strong attachment. Based on these findings, we expect smartphone attachment to play a moderating role and predict that participants more strongly attached to their smartphones will be affected more negatively by their smartphones' presence than participants less attached.

H3: Smartphone attachment increases the impact of smartphone presence on Ospan scores.

Fear of Missing Out

As it seems, people are becoming increasingly dependent on social media to fulfill their social needs (e.g. Lee & Chiou, 2013), their smartphones serving as a means thereto. Przybylski, Murayama, DeHaan, and Gladwell (2013) suggest that deficits in psychological needs decrease people's well-being, resulting in compensation behaviors. This is in line with Self-Determination Theory (Ryan & Deci, 2000) which proposes that people have basic psychological needs, namely competence, autonomy and relatedness, which they will try to compensate if not satisfied. According to Przybylski et al. (2013), the construct fear of missing out can be understood as a compensating mechanism arising from deficits in these psychological needs. Przybylski et al. (2013) suggest that people whose psychological needs are not fulfilled may be more sensitive to missing out on things which may drive them to depending on social media and their smartphones as a self-regulatory means. As fear of missing out seems to play a role in the connection to one's smartphone, we attempt to detect any effects it has on working memory capacity while smartphones are present.

RQ1: How does fear of missing out influence the relationship between smartphone presence and available working memory capacity?

Method

To examine the effects of smartphone presence, smartphone attachment and fear of missing out on available working memory capacity, we recruited participants and had them take an online test followed by a variety of scales measuring the constructs. The experimental design was a between-subject design with random assignment of each participant to one of two conditions: smartphone present and smartphone absent. The study was carried out in a laboratory under controlled conditions where participants in groups of two to fifteen, depending on the number of registrations per open slot, completed the online survey.

Participants

One hundred and five participants were recruited using the online study tool of the University of Basel. Six participants were excluded as their smartphones were not in the location they should have been depending on the condition they were assigned to. This was assessed by including a control question asking the participants at the end of the study where their smartphones were located while completing the survey. The answers of the six participants excluded did not match the location their smartphones were supposed to have been. Of the 99 remaining participants, 70.7% were female and 29.3% male. The great majority of the participants were psychology students, namely 81.8%. Their age ranged from 19 to 70 years ($M = 24.19$, $Mdn = 22$, $SD = 6.44$).

Two participants reported having difficulties understanding the questions in English. Also, one participant explained they had been diagnosed with Attention Deficit Hyperactivity Disorder and that their performance was therefore generally inferior to others'.

Materials

To measure the effects of smartphone presence, smartphone attachment and fear of missing out on participants' cognitive performance, a variety of validated scales was used.

Available working memory capacity. To predict performance on cognitive tasks and to measure available working memory capacity, working memory span tasks have proven to be reliable (Engle, Tuholski, Laughlin, & Conway, 1999). Several versions exist which all have in common that they require participants to remember a sequence of items while being distracted by other activities. Unsworth, Heitz, Schrock, and Engle (2005) developed an automated version of the task, the Operation Span Task (Ospan), originally designed by Turner and Engle (1989), which consists of a series of math operations and unrelated words. Participants solve math problems while remembering the words presented to them.

To measure participants' available working memory capacity, we used a slightly adapted version of the Ospan task which required participants to alternately judge random statements on their truth and memorize the numbers displayed. The quantity of numbers to be memorized per trial grew from two to four over five trials. Depending on the quantity of numbers recalled correctly, participants received a score for the number of targets correctly recalled for each trial and a final score for the whole test.

Cognitive Reflection Test. To assess the depth of information processing, participants also completed the Cognitive Reflection Test. The test consists of 7 questions, each requiring the participant to override an intuition for a more elaborate response. An example item is: "A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?”. All items are presented in the Appendix in Table 1. The purpose of this test is to measure the depth of information processing. Participants who are not able to concentrate their complete working memory capacity on the focal task are expected to process less deeply and therefore achieve lower scores on the Cognitive Reflection Test.

The Cognitive Reflection Test was carried out on the same participants. It was, however, part of a different study with similar research questions (Stahl, 2018). In preparation for this study, a preliminary study was conducted with the aim of discovering potential sequence effects between the Ospan task and the Cognitive Reflection Test. Even though there were no significant sequence effects ($t(37) = 0.18$, $p = .86$ for the Ospan task and $t(35) = -0.79$, $p = .43$ for the Cognitive Reflection Test) between the two, we decided to keep the randomization of participants between the two sequences as to maintain consistency. As the Cognitive Reflection Test is not part of this study, we will not report findings on this scale.

Attentional Control Scale. To measure individual differences in attentional control, participants completed the Attentional Control Scale. The scale consists of 12 items, each on a four-point Likert scale ranging from 1 (almost never) to 4 (always). An example item is: “It’s very hard for me to concentrate on a difficult task when there are noises around”. The complete set of items is listed in the Appendix in Table 2. The Attentional Control Scale was part of a different study with similar research questions (Stahl, 2018). Findings on this scale will therefore not be reported.

Smartphone attachment. To measure participants’ attachment to their smartphones we applied the Possession Attachment Scale developed by Weller et al. (2013). This scale consists of five items, each on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), Cronbach's alpha = .74, mean interitem *r* = .37. Each participant received an overall score resulting of the sum of all item scores. An example item is: "I would feel uncomfortable if I didn't have my phone with me for a long period of time". All items are presented in the Appendix in Table 3.

Fear of missing out. To measure participants' fear of missing out on opportunities we had them self-report using the Fear of Missing Out Scale developed by Przybylski et al. (2013) which consists of 10 items, each of which are rated on a five-point Likert scale ranging from 1 (not at all true of me) to 5 (extremely true of me), Cronbach's alpha = .78, mean interitem *r* = .26. Each participant received an overall score resulting of the sum of all item scores. An example item is: "I feel others have more rewarding experiences than me". The complete set of items is listed in the Appendix in Table 4.

Procedure

Participants were randomly assigned to one of two conditions, either smartphone present (*n* = 51) or smartphone absent (*n* = 48). In the smartphone present condition, participants were instructed to put all belongings to the side of the room, including their pockets' contents, except for their smartphone. They were told they would need their smartphone for a task later in the study and should therefore place it within reach face down on the table. Participants in the smartphone absent condition were instructed to place all belongings to the side of the room, including their pockets' contents. Their smartphones were explicitly not mentioned as to not raise any suspicion about the study's actual purpose.

All participants in both conditions were presented with almost identical materials in the same sequence. First, they gave their consent by signing a consent form before commencing with the study. Next, they read instructions on the screen after which they started with either the

Ospan task or the Cognitive Reflection Test. After completing both the Ospan task and the Cognitive Reflection Test (in randomized order) participants were asked if they had any idea what the hypothesis of the study was. Next, participants completed the Attentional Control Scale (used for a different study along with the Cognitive Reflection Test), the Fear of Missing Out Scale and the Smartphone Attachment Scale. After completion of these scales participants were asked where their smartphone was located and if they had thought about it at any time during the study. Participants who stated they had thought about their smartphone at some time during the study were then asked if they expected their smartphone-directed thoughts to have influenced their performance generally or in a positive or negative direction.

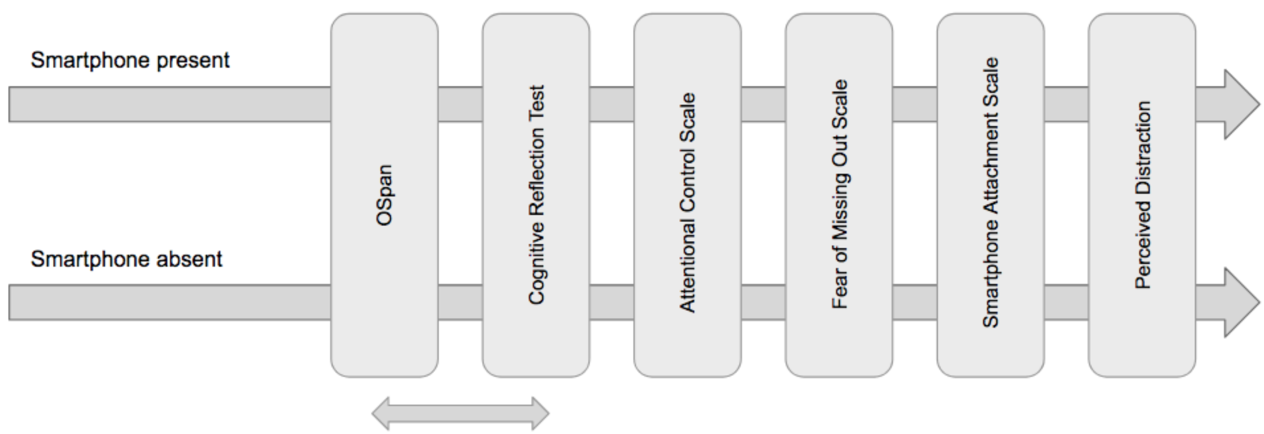

Figure 1. Visualization of the study procedure in chronological order.

All participants were then presented with demographic questions including age, gender and current occupation. At the end of the study, participants were asked how seriously they completed the study and had the possibility to submit any comments. Finally, participants who wished to do so entered their email address to participate in the draw of a shopping voucher. The complete procedure of the study is shown in Figure 1.

Results

Results were calculated using the statistical programming language R with the additional packages psych, qqplotr, hmisc and effsize. All analyses were conducted and reported at the critical significance level of 0.05.

Ospan Task

To test for differences in working memory capacity in presence or absence of their smartphones (H1), a total score was calculated for each participant for the Ospan task with a minimum of 0 and a maximum of 16 points (*M* = 11.02, *SD* = 2.99). Four participants achieved the maximum score. One outlier was removed where the total Ospan score was 1.

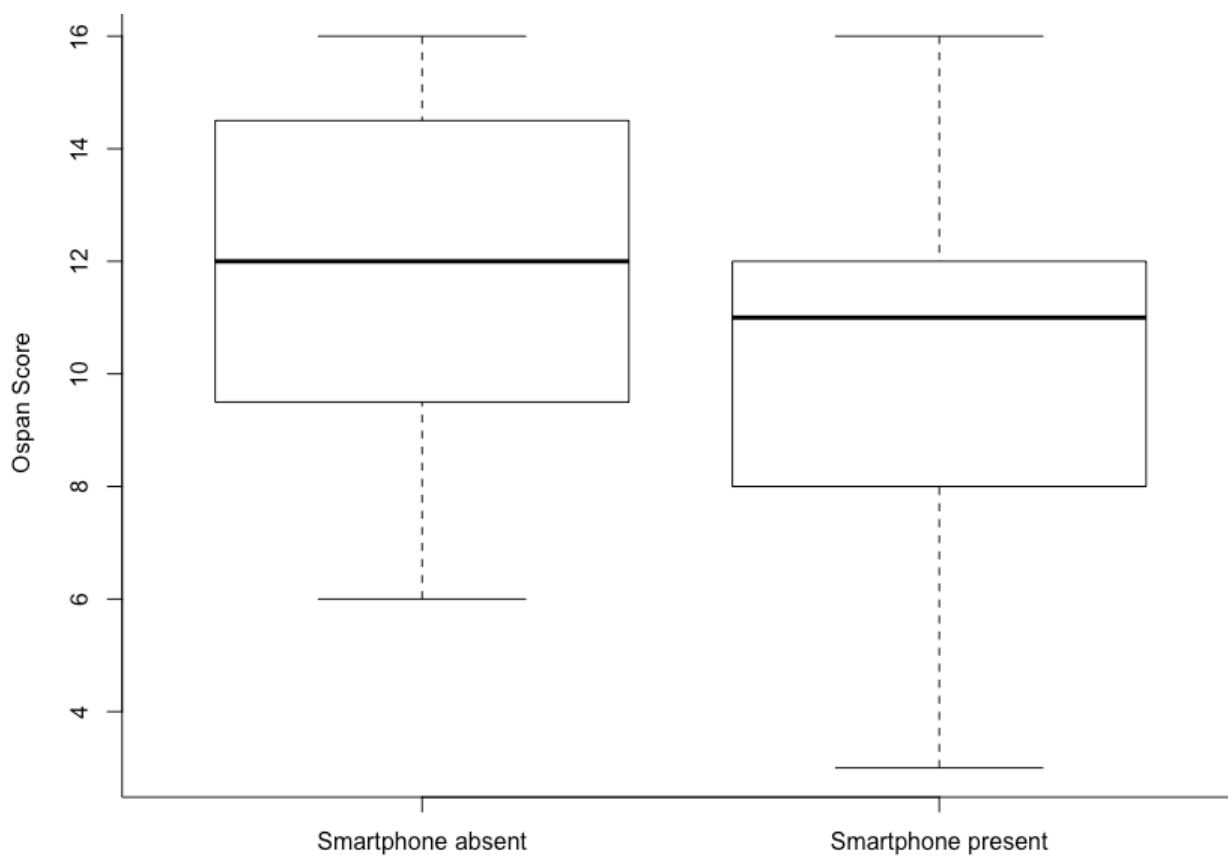

Figure 2. Difference of Ospan score distribution between conditions.

As shown in Figure 2, differences can be identified when comparing the two conditions in which participants' smartphones were either present or absent during the study. Ospan scores were lower when smartphones were present (*M* = 10.43, *Mdn* = 11.00, *SD* = 3.00) than when they were absent (*M* = 11.66, *Mdn* = 12.00, *SD* = 2.89).

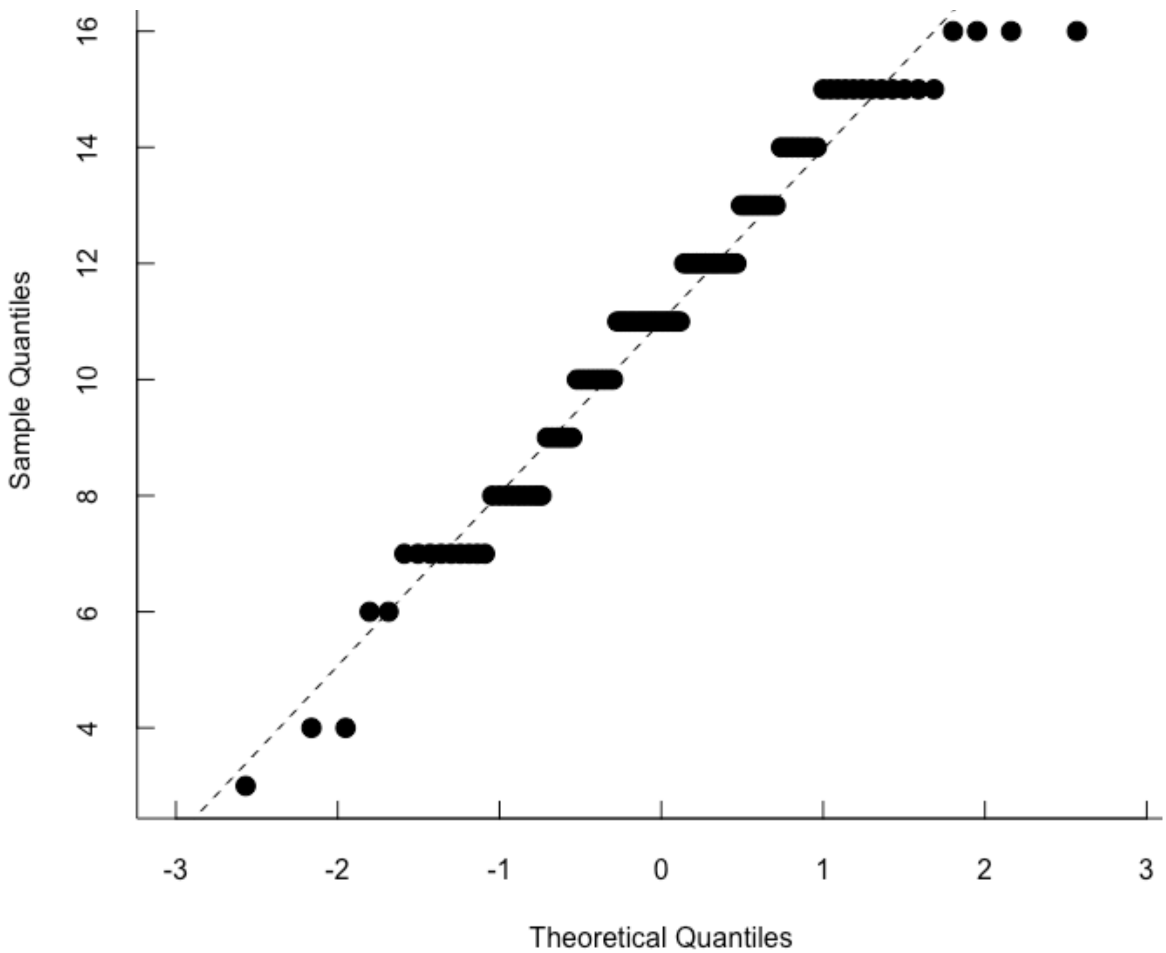

Figure 3. Normal Q-Q plot of sample quantiles compared with theoretical quantiles.

Due to the non-normal distribution of the data as seen in Figure 3, we conducted a Wilcoxon rank sum test. This analysis confirmed the observation and indicated that Ospan scores were significantly lower when smartphones were present than when they were absent (W = 1464.5, p = .03, r = -.22, d = .42), thereby supporting H1.

Subjective Distraction

To test for the awareness of the effects their smartphones' presence had (H2), participants' self-reported ratings were analyzed using t-tests for independent samples. Participants in the smartphone present condition reported significantly more often of having thought about their smartphones at least once during the study, whereas participants in the smartphone absent condition reported never having thought about it ($t(50) = -3.05$, $p = .004$, $d = -.59$).

When asked about the general influence their smartphones' location had on their performance, participants' subjective opinions did not differ significantly between the two conditions ($M = 1.63$ for participants whose smartphones were absent and $M = 1.96$ for participants whose smartphones were present), both assuming no potential influence ($t(96.57) = -1.44$, $p = .15$). Next, participants were asked if they thought their smartphones had a positive influence on their performance. Whereas participants across conditions objected, participants in the smartphone present condition objected significantly more strongly ($M = 1.47$) than participants in the smartphone absent condition ($M = 2.23$). In other words, participants whose smartphones were present rejected a possible positive effect on their cognitive performance more strongly than participants whose smartphones were absent ($t(75.13) = 3.68$, $p < .001$, $d = .75$). In a similar vein, participants in the smartphone absent condition objected to a negative influence of their smartphones' location significantly more strongly than their counterparts ($t(85.01) = -2.40$, $p = .02$, $d = -.48$). Accordingly, participants whose smartphones were present suspected their smartphones had a more negative influence on their performance than participants whose smartphones were absent.

These results provide mixed support for H2. One the one hand, there was no difference between the groups when asked about any influence in general, indicating that participants were indeed not aware of any effects their smartphones' presence had on their performance. This finding supports H2. On the other hand, when asked about the nature of potential effects, participants whose smartphones were present did believe they were influenced negatively and vice versa. This finding indicates that said participants did suspect their smartphones' presence to have influenced their performance, suggesting a rejection of H2. The latter results are shown in Figure 4.

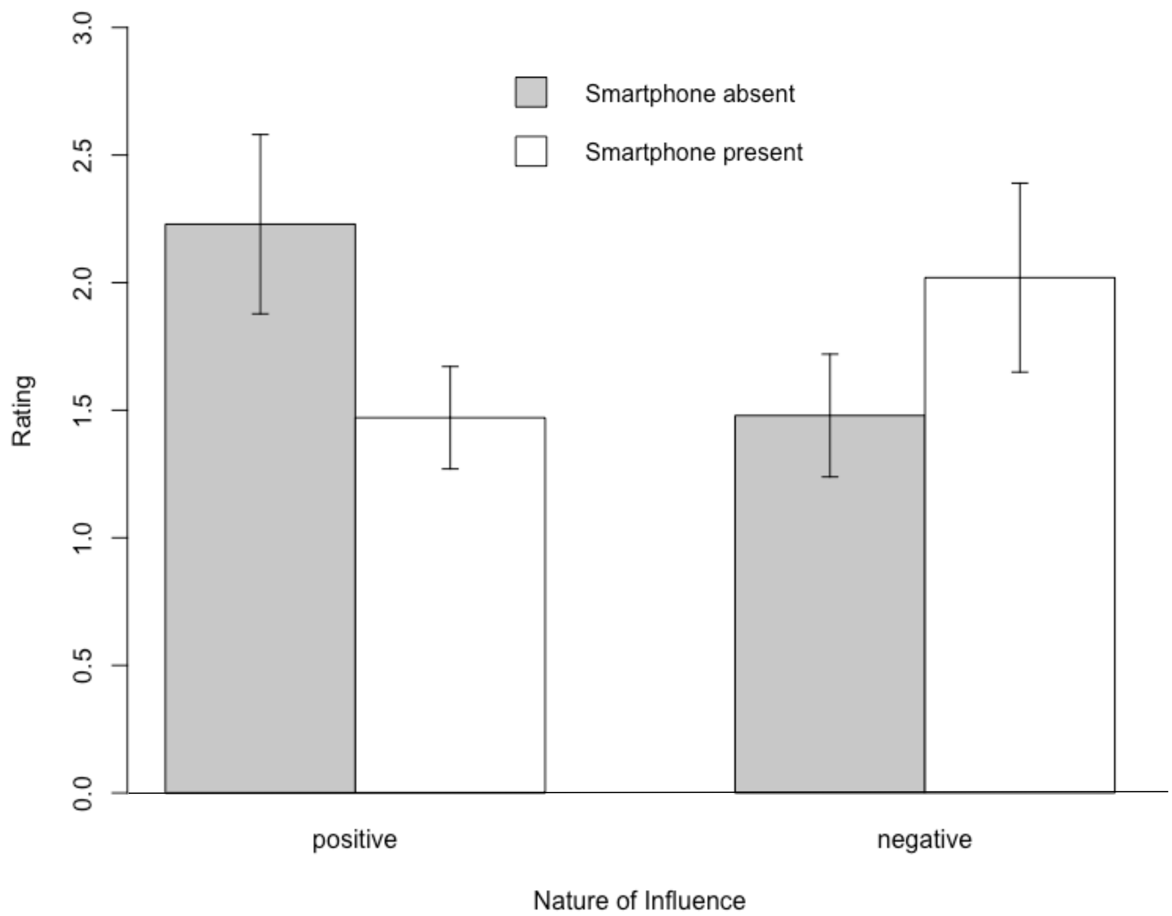

Figure 4. Comparison of conditions and suspected nature of influence (positive or negative). The whiskers represent the standard errors.

Smartphone Attachment

To investigate the influence of smartphone attachment (H3), we compared the reported smartphone attachment ratings between the groups. Endorsement rates for the Smartphone Attachment Scale items are shown in the Appendix in Table 1. Overall, most participants, namely 60.6%, reported they would feel uncomfortable if they did not have their smartphone with them for a long period of time. 59.6% of all participants reported they would feel lost and 53.6% would feel detached from their friends if they did not have a smartphone. Furthermore, 45.4% of all participants reported they would feel momentarily distressed if they realized that they were without their smartphone while out and about. 23.3% of all participants would rather lose their wallet than their smartphone.

Each participant was given an overall score as the average of all Smartphone Attachment Scale items, ranging from 1 to a maximum of 5 ($M = 3.17$, $Mdn = 3.2$, $SD = 0.86$). Overall smartphone attachment scores did not differ significantly between the two conditions ($t(94.61) = -.86$, $p = .39$), nor did any of the individual items ($t(90.54) = -1.12$, $p = .27$ for item 1; $t(94.22) = -.84$, $p = .40$ for item 2; $t(87.48) = -.81$, $p = .42$ for item 3; $t(94.04) = .61$, $p = .54$ for item 4; $t(95.84) = -.89$, $p = .37$ for item 5).

Regarding the influence of smartphone attachment on Ospan scores, there was a negative correlation between the two variables ($r = -.2$, $p = .047$). A linear regression also revealed a significant main effect of smartphone attachment on Ospan scores ($F(1, 96) = 4.062$, $p = .047$) as shown in Figure 5.

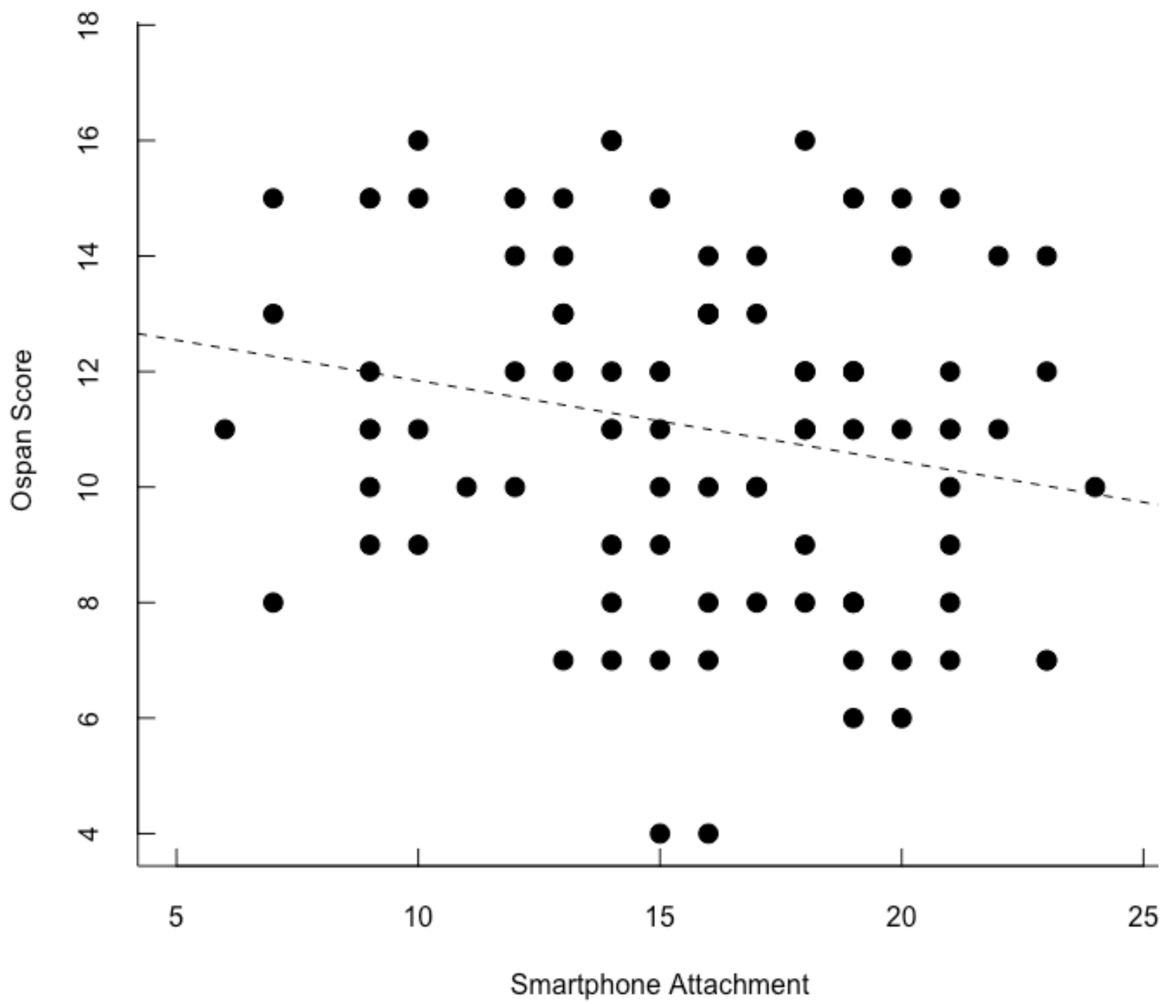

Figure 5. Distribution of Ospan and smartphone attachment scores with regression line.

To test for moderating effects smartphone attachment have on the relationship between smartphone presence and Ospan scores, a multiple linear regression analysis was conducted. Two models were compared. The first model did not include the moderation terms whereas the second did. A one-way ANOVA revealed no significant difference between the models ($F(1, 94) = .66$, $p = .42$). Thus, smartphone attachment is not a significant moderator of the relationship between smartphone presence and Ospan scores. Therefore, H3 is rejected.

Fear of Missing Out

Endorsement rates for the Fear of Missing Out Scale are shown in the Appendix in Table 2. Around 40% of all participants feel others, or specifically their friends, have more rewarding experiences than them. Few participants, namely around 12%, feel anxious when they do not know what their friends are doing. Many do, however, place importance on understanding their friends' "in jokes". Most participants are bothered when they miss an opportunity to meet up with their friends. Interestingly, very few participants reported it being important to them to share the details online when having a good time.

Each participant received an overall score between 1 and 5 calculated as the average of all 10 Fear of Missing Out Scale items ($M = 2.27$, $Mdn = 2.3$, $SD = .60$). An analysis of the relationship between fear of missing out and smartphone attachment revealed a significant correlation ($r = .29$, $p = .004$). Next, the relationship between fear of missing out and Ospan scores was examined. A linear regression revealed no main effect of fear of missing out ($F(1, 94) = .20$, $p = .66$) and no interaction between fear of missing out and experimental condition ($F(1, 94) = .33$, $p = .57$). Therefore, fear of missing out neither moderated the relationship between smartphone presence and Ospan scores nor explained the differences on Ospan scores across conditions. Using linear regression, we also failed to find a mediation effect of fear of missing out explaining the relationship between smartphone presence and Ospan scores. The relation between the predictor condition and outcome Ospan scores was significant ($F(1, 96) = 4.25$, $p = .04$). The relation between the predictor condition and supposed mediator fear of missing out was not significant ($F(1, 96) = .19$, $p = .66$). Also, there was no significance of the predictor condition in the full model ($F(2, 95) = 2.21$, $p = .12$).

In a more exploratory vein, we found that fear of missing out did not correlate significantly with gender (r = -.12, p = .23). It did however correlate significantly with participants' age (r = -.23, p = .03) in a negative direction, suggesting that the older people are, the less anxious they are about missing out.

Discussion

The aim of this study was to investigate the influence of smartphone presence on available working memory capacity, indirectly measured using the Ospan task. Next, participants' self-reported feeling of distraction by their smartphones was analyzed, the expectation being that participants are not aware of the distracting effects their smartphones have. Furthermore, smartphone attachment, fear of missing out and their potential influence on the relationship between smartphone presence and Ospan scores were investigated. In the following sections, these results as well as future research possibilities are discussed.

Smartphone Presence and Available Working Memory Capacity

Negative effects of smartphone presence on cognitive performance were found, consistent with findings of Ward et al. (2017) and Thornton et al. (2014). According to Ward et al. (2017), declination of cognitive performance in presence of a smartphone is due to the distraction, diverting some portion of attention away from the task and thus diminishing available working memory capacity. As the Ospan task measures available working memory capacity (Engle et al., 1999) and Ospan results were lower when smartphones were present, we can conclude that this circumstance reduces available working memory capacity. Therefore, people need to be aware that the presence of their smartphones while completing cognitive demanding tasks can affect their performance in a negative manner.

Another possible factor which needs to be considered in further research is the distraction by others' smartphones. Fried (2008) found that laptop use during a lecture impairs their users' and fellow students' learning. This might also apply to the experimental setting in this study since participants were seated next to each other, each in close proximity to others' smartphones.

Subjective Distraction

When asked how often they thought about their smartphones, participants whose smartphones were present reported having thought about them more often than those whose smartphones were absent. This finding matches the results referred to above, confirming the distracting effect smartphone presence has on people's attention. Therefore, it can be deduced that people need to pay special attention to the whereabouts of their smartphones before initiating any cognitively challenging task.

Furthermore, when asked if their smartphones' presence had any effect on their performance, participants across conditions objected. This result is consistent with the findings of Ward et al. (2017), indicating that people whose smartphones were present were not aware of the effects they had on their cognitive performance. Interestingly though, when asked about the nature of potential effects on cognitive performance, participants between conditions disagreed on the extent to which their smartphones' presence had influenced them positively or negatively. This finding indicates that participants were somewhat aware of the harmful effects their smartphones' presence had.

In summary, while first objecting to a general influence their smartphones might have, the explicit question of the influence's nature may have sparked some doubt in participants' responses of their smartphones having no effects at all. The explicit mentioning of the influence's nature on participants' cognitive performance may have led them to reflect on possible influences more carefully and therefore resulted in them making less opposed assumptions about *any* influence. To test this possibility, further research could involve asking participants about potential general, positive and negative influence in randomized order to control for any sequence effects.

Smartphone Attachment

Concerning the significantly negative correlation between smartphone attachment and Ospan scores, these results are as expected. This result leads to the presumption that smartphones need *not* be present in order to negatively affect cognitive processes. Thus, if this presumption holds true, being strongly attached to one's smartphone can have severe effects, even when it is out of sight. In summary, participants who are attached more profoundly to their smartphones are particularly at risk of being distracted while completing cognitively demanding tasks. To confirm this assumption and to prove causality, further research needs to be conducted.

Contrary to our expectations, smartphone attachment did not moderate the relationship between smartphone presence and Ospan scores. It was expected that smartphone presence would affect participants more who were strongly attached to their smartphones. Since the level of smartphone attachment did not play a role in the smartphone presence and Ospan model, people need to be aware of the effects their smartphones' presence can have even if they do not consider themselves to be heavily attached. The underlying mechanism of this finding ought to be studied in further research. Other constructs in need of further clarification are smartphone dependence and smartphone addiction. Whereas smartphone attachment does not moderate the relationship between smartphone presence and Ospan scores, it is possible that dependence on or addiction to smartphones may play an important role on working memory capacity.

Fear of Missing Out

The correlation found between smartphone attachment and fear of missing out is unsurprising considering the assumption that fear of missing out roots in the need for belonging and social acceptance (Przybylski et al., 2013), which are often satisfied through smartphones. Surprisingly though, fear of missing out did not have any effects, neither explaining any differences, nor mediating or moderating relationships. A possible explanation is that while answering the questions on the Smartphone Attachment Scale participants thought about their answers while possibly just having realized the presence or absence of their smartphones was the actual subject of the study. While answering the questions on the Fear of Missing Out Scale, however, participants were presumably not yet aware of their smartphones being subject to the study as this was not the subject of the questions. This knowledge may have led participants to think about their answers on the Smartphone Attachment Scale in a different way compared to their answers on the Fear of Missing Out Scale. Further research needs to confirm this by randomizing the order in which the constructs are measured. Another possibility is to explicitly enlighten participants about the actual subject of the study before asking any questions about their smartphone attachment. By doing this, participants do not answer the questions in a state of surprise caused by the questions themselves.

A significant negative correlation between fear of missing out and age was found, implying that younger people are more anxious about missing out than older people. This finding must be taken note of with caution due to the irregular distribution of age in the sample with 75% of all participants being under 25 years old. Further research ought to examine this issue with a more balanced sample.

Practical Implications

Most importantly, this study succeeds in showing that smartphone presence does indeed affect cognitive performance negatively. Also, people are not necessarily aware of any distracting effects their smartphones have on them. Therefore, people ought to be aware of this while studying or completing other cognitively demanding tasks even if they do not assume any negative influences of their smartphones. Furthermore, the argument of not being heavily attached to one's smartphone needs to be considered with caution since it is possible smartphone presence influences cognitive performance even when not strongly attached.

Limitations

The findings presented in this paper are not without limitations. For instance, the results can possibly not be generalized without constraints as the sample consisted of mostly psychology students, most of which were under 25 years of age. Future research needs to be conducted in order to enable a generalization over a more diverse sample.

Furthermore, although participants in the smartphone present condition were instructed to place their smartphones face down, this was not controlled. Hence, it is possible that some participants had their smartphones face up and were therefore influenced differently than participants whose smartphones were face down as instructed. Future research ought to control the exact placement of participants' smartphones to ensure it does not act as a confounder.

Also, some participants may have been expecting important news like test results and were therefore extraordinarily distracted by their smartphones' likelihood of these news being delivered rather than by their mere presence. Controlling for this variable would require a technical solution which complies with both ethical standards and data protection laws.

Conclusion

In summary, this study shows that the mere presence of people's smartphones influences available working memory capacity, resulting in reduced cognitive performance. Furthermore, this effect occurs without people necessarily realizing it. These findings have practical implications which need to be taken into consideration. When attempting to perform cognitively demanding tasks, people ought to reflect on these findings and put their smartphones out of sight to avoid any negative impact and to be able to reach their full potential.

References

Caird, J. K., Willness, C. R., Steel, P., & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis & Prevention*, *40*(4), 1282-1293.

Cheever, N. A., Rosen, L. D., Carrier, L. M., & Chavez, A. (2014). Out of sight is not out of mind: The impact of restricting wireless mobile device use on anxiety levels among low, moderate and high users. *Computers in Human Behavior*, *37*, 290–297.

Clayton, R. B., Leshner, G., & Almond, A. (2015). The Extended iSelf: The Impact of iPhone Separation on Cognition, Emotion, and Physiology. *Journal of Computer-Mediated Communication*, *20*(2), 119–135.

Conway, A. R., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, *8*(2), 331-335.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671-684.

De Fockert, J. W., Rees, G., Frith, C. D., & Lavie, N. (2001). The role of working memory in visual selective attention. *Science*, *291*(5509), 1803-1806.

Duncan, D. K., Hoekstra, A. R., & Wilcox, B. R. (2012). Digital devices, distraction, and student performance: Does in-class cell phone use reduce learning? *Astronomy Education Review*, *11*(1).

End, C. M., Worthman, S., Mathews, M. B., & Wetterau, K. (2010). Costly cell phones: The impact of cell phone rings on academic performance. *Teaching of Psychology*, *37*(1), 55-57.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. (1999). Working memory, short-term memory, and general fluid intelligence: a latent-variable approach. *Journal of Experimental Psychology: General*, *128*(3), 309.

Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education*, *50*(3), 906-914.

Froese, A. D., Carpenter, C. N., Inman, D. A., Schooley, J. R., Barnes, R. B., Brecht, P. W., & Chacon, J. D. (2012). Effects of classroom cell phone use on expected and actual learning. *College Student Journal*, *46*(2), 323-333.

Hyman Jr, I. E., Boss, S. M., Wise, B. M., McKenzie, K. E., & Caggiano, J. M. (2010). Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. *Applied Cognitive Psychology*, *24*(5), 597-607.

Lee, C. C., & Chiou, W. B. (2013). Keep logging in! Experimental evidence showing the relation of affiliation needs to the idea of online social networking. *Cyberpsychology, Behavior, and Social Networking*, *16*(6), 419-422.

Lesch, M. F., & Hancock, P. A. (2004). Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis & Prevention*, *36*(3), 471-480.

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, *11*(1), 56-60.

Przybylski, A. K., Murayama, K., DeHaan, C. R., & Gladwell, V. (2013). Motivational, emotional, and behavioral correlates of fear of missing out. *Computers in Human Behavior, 29*(4), 1841-1848.

Przybylski, A. K., & Weinstein, N. (2013). Can you connect with me now? How the presence of mobile communication technology influences face-to-face conversation quality. *Journal of Social and Personal Relationships*, *30*(3), 237-246.

Roye, A., Jacobsen, T., & Schröger, E. (2007). Personal significance is encoded automatically by the human brain: an event-related potential study with ringtones. *European Journal of Neuroscience*, *26*(3), 784-790.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68.

Salvucci, D. D., Taatgen, N. A., & Borst, J. P. (2009, April). Toward a unified theory of the multitasking continuum: From concurrent performance to task switching, interruption, and resumption. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1819-1828). ACM.

Stahl, L. (2018). *Smartphone presence and its impact on cognitive impairment* (Master's thesis).

Stothart, C., Mitchum, A., & Yehnert, C. (2015). The attentional cost of receiving a cell phone notification. *Journal of Experimental Psychology: Human Perception and Performance*, *41*(4), 893.

Thornton, B., Faires, A., Robbins, M., & Rollins, E. (2014). The Mere Presence of a Cell Phone May be Distracting. *Social Psychology*, *45*(6), 479–488.

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language*, *28*(2), 127-154.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, *37*(3), 498-505.

Ward, A. F., Duke, K., Gneezy, A., & Bos, M. W. (2017). Brain Drain: The Mere Presence of One's Own Smartphone Reduces Available Cognitive Capacity. *Journal of the Association for Consumer Research*, *2*(2), 140–154.

Weller, J. A., Shackleford, C., Dieckmann, N., & Slovic, P. (2013). Possession attachment predicts cell phone use while driving. *Health Psychology*, *32*(4), 379.

Appendix

Table 1

Cognitive Reflection Test Items

Item
1. A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?
2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?
4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together?
5. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class?
6. A man buys a pig for $60, sells it for $70, buys it back for $80, and sells it finally for $90. How much has he made?
7. Simon decided to invest $8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has: broken even in the stock market; is ahead of where he began; has lost money

Note: All items, except for item 7, were accompanied with text fields where the participants were able to freely enter their answers. Item 7 had 3 possible answers of which participants made their choice.

Table 2

Attentional Control Scale Items

Item
1. It's very hard for me to concentrate on a difficult task when there are noises around.
2. When I need to concentrate and solve a problem, I have trouble focusing my attention.
3. When I am working hard on something, I still get distracted by events around me.
4. When I am reading or studying, I am easily distracted if there are people talking in the same room.
5. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
6. I have a hard time concentrating when I'm excited about something.
7. I can quickly switch from one task to another.
8. It is difficult for me to co-ordinate my attention between the listening and writing required when taking notes during lectures.
9. I can become interested in a new topic very quickly when I need to.
10. After being interrupted or distracted, I can easily shift my attention back to what I was doing before.
11. When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
12. It is easy for me to alternate between two different tasks.

Note: All items were answered on a 4-point Likert scale ranging from 1 (almost never) to 4 (always).

Table 3

Endorsement Rates for Perceived Smartphone Attachment Items

Item	Strongly disagree	Somewhat disagree	Neutral (neither agree nor disagree)	Somewhat agree	Strongly agree
1. I would feel uncomfortable if I didn't have my phone with me for a long period of time.	5.1	21.4	13.3	40.8	19.4
2. I would feel lost if I didn't have a cell phone.	7.1	20.4	12.2	40.8	19.4
3. I would feel detached from my friends if I didn't have a cell phone.	6.1	19.4	20.4	36.7	17.3
4. I feel momentarily distressed if I realize that I am without my phone while I am out and about.	11.2	23.5	19.4	32.7	13.3
5. I would rather lose my wallet than my phone.	35.7	17.3	24.5	16.3	6.1

Note: All items were answered on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). All numbers are rates and are to be interpreted as percentages.

Table 4

Endorsement Rates for Fear of Missing Out Scale Items

Item	Not at all true of me	Slightly true of me	Moderately true of me	Very true of me	Extremely true of me
1. I fear others have more rewarding experiences than me.	18.4	37.8	26.5	16.3	1.0
2. I fear my friends have more rewarding experiences than me.	27.6	32.7	22.4	16.3	1.0
3. I get worried when I find out my friends are having fun without me.	25.5	31.6	26.5	14.3	2.0
4. I get anxious when I don't know what my friends are up to.	59.2	28.6	9.2	3.1	0
5. It is important that I understand my friends' "in jokes".	11.2	34.7	21.4	27.6	4.1
6. Sometimes, I wonder if I spend too much time keeping up with what is going on.	31.6	31.6	18.4	15.3	3.1
7. It bothers me when I miss an opportunity to meet up with friends.	11.2	34.7	19.4	29.6	5.1
8. When I have a good time it is important for me to share the details online (e.g. updating status).	81.6	16.3	2.0	0	0
9. When I miss out on a planned get-together it bothers me.	10.2	29.6	19.4	29.6	10.2
10. When I go on vacation, I continue to keep tabs on what my friends are doing.	41.8	31.6	12.2	14.3	0

Note: All items were answered on a 5-point Likert scale ranging from 1 (not at all true of me) to 5 (extremely true of me). All numbers are rates and are to be interpreted as percentages.