Mind Wandering in a Smartphone World: The Impact of Pervasive Smartphone Usage on Mind Wandering and Attentional Restoration

Mind Wandering in a Smartphone World: The Impact of Pervasive Smartphone Usage on Mind Wandering and Attentional Restoration

Mariam Khayretdinova

A Thesis in the Field of Psychology

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2022

Abstract

Mind-wandering is a cognitive process that often occurs during idleness and rest. Nowadays, due to the rise of the smartphone's popularity, people tend to spend most of their free time on their mobile devices. Previous research has evaluated the primarily negative impact of both mind-wandering and smartphone usage during attention and performance tasks. The aim of this work was to investigate the impact of smartphone usage and mind-wandering during periods of rest on one's ability to maintain attention during a subsequent task. In this study, participants ($N = 129$) completed an attentional network test, under two conditions: (a) without breaks between test sections and (b) with two breaks, which they spent either using their smartphones or letting their minds wander. Results indicate that the smartphone break led to higher levels of mind-wandering during the task, compared to other conditions. Moreover, the smartphone break improved performance and reduced reaction time during the task. The present findings confirm the complexity of the relationship between attention and mind-wandering, as well as between attention and smartphone usage. Future studies should address these findings and reexamine previous assumptions that mind-wandering and attention, and smartphone usage and attention are anticorrelated processes.

Table of Contents

List of Tables

List of Figures

Chapter I

Introduction

Mind-wandering is a cognitive process that recruits the default mode network (DMN), a large brain network for which activation is associated with the basal resting state and light sleep (Andrews-Hanna, 2012; Christoff et al., 2016). To provide a comprehensive definition of mind-wandering, Smallwood & Schooler (2006) analyzed papers that referred to such states of mind as “task-unrelated thoughts,” “task-unrelated images,” “zoning out,” “stimulus-independent thoughts,” and “mind pops.” They found that a common denominator for these states is “a shift of attention away from the primary task towards internal information, such as memories” (Smallwood & Schooler, 2015). Indeed, mind-wandering has often been studied in relation to attention (Galéra et al., 2012; Randall et al., 2014; Risko et al., 2012; Thomson et al., 2014; Yanko & Spalek, 2014), which can be explained by the complementary nature of the relationship between the DMN and attentional networks (Christoff et al., 2016): namely, when one network is activated less, its complementary network is activated more (Raichle, 2015).

Psychology research has also demonstrated that mind-wandering during task activities shifts one’s attention from the primary task to task-unrelated thoughts, often affecting performance. As a result, mind-wandering is often defined as task-unrelated thoughts (TUTs). However, according to Murray et al. (2020), this definition is inaccurate because it does not include the main time when mind-wandering occurs, and the DMN activates: periods of rest. At the same time, it is little known about the relationship between attention and mind-wandering during periods of rest. However, studies demonstrate that rest facilitates one's attention for the subsequent task (Helton & Russell, 2015; 2017), which leads to the idea that mind-wandering may contribute to the restoration of one's attention.

Due to the rise of smartphone popularity (Deloitte, 2018), people tend to spend their idle time— such as waiting in line, during a bus ride, or while resting—on their mobile devices. As an experiment by Markowitz et al. (2019) demonstrated, one's level of mind-wandering decreases when using a smartphone. The same might be true if mind-wandering is perceived as a process associated with activation of the DMN. Due to the high flow of information, the intensity of visual stimuli (e.g., bright lights, different colors, rapidly changing content) and one's engagement in a variety of tasks (e.g., reading, writing, playing games; (Fan et al., 2005; Raz, 2004), smartphone use may recruit attentional networks. At the same time, this recruitment is expected to decrease activation of the DMN (Raichle, 2015). Therefore, this work aims to answer two questions: Do mind-wandering episodes during rest facilitate one's ability to focus during a subsequent task, and does smartphone usage, in contrast with pure mind-wandering, affect one's ability to maintain sustained attention during a subsequent task?

Mind Wandering and Attention

Vast amounts of research have examined mind-wandering as the opposite state of attention (Galéra et al., 2012; Randall et al., 2014; Risko et al., 2012; Thomson et al., 2014; Yanko & Spalek, 2014). Notably, most of these studies focus on the process of mind-wandering during an ongoing activity or main task to which participants should pay attention. For instance, studies have demonstrated that mind-wandering while driving can lead to car accidents by decoupling attention (Galéra et al., 2012; Yanko & Spalek, 2014). Similar results have been found regarding mind-wandering in academic settings, where sustained attention is required from students during class to memorize the information provided (Risko et al., 2012). Such research demonstrates that mind-wandering impairs student performance, measured as the memorization of materials provided during lectures, due to lapses in attention.

Other studies presented tasks to participants in a laboratory setting and produced similar results (Randall et al., 2014; Thornton, 2014). These findings support previous theories that mind-wandering is a type of thinking that shifts an agent's attention from a primary task to internal thoughts, leading to a less detailed representation of one's external environment (Smallwood et al., 2007). Notably, studies have demonstrated that an increase in mind-wandering correlates with task duration; simply put, the longer the period of attention required, the more that mind-wandering occurs (Baldwin et al., 2017; Farley et al., 2013; Thomson et al., 2014; Risko et al., 2012). These studies lead the idea, that mind-wandering is an inevitable process of the brain, and brain itself switches attention from the task to external environment in order to be able to re-focus on the task.

Indeed, a few studies have analyzed mind-wandering as a natural process that occurs during rest or breaks; these studies also examined mind-wandering's possible impact on attention during a subsequent task (Merlo et al., 2020; Williams et al., 2018). The results of such research indicate that mind-wandering during rest or breaks may play a role in the process of attentional restoration or facilitate attention during a subsequent task (Helton & Russell, 2015; 2017). According to Helton and Russell (2015), one of the similar to mind-wandering processes is an under-load theory, also known as monotony theory (Eastwood et al., 2012) . This theory covers the neural mechanisms that occur in the state of boredom when cognitive resources are disengaged. Boredom can also be defined as the opposite experience of wanting, though, being unable to be involved in the pleasant activity (Eastwood et al., 2012). It is closely tied to the functions of attention and occurs when the person is unable to engage his/her attention towards the internal (feelings and thoughts), as well as external (outside stimuli). Unlike, the mind-wandering that focuses the attention on the internal stimuli. It often occurs during the monotonous task, when the individual is not in the active state of vigilance, for example when performing the same task repeatedly (Unsworth & Robison, 2018). Moreover, Helton and Russell et al. (2015) state that boredom is linked to mind-wandering functionally. Some of the previous research has shown that the activity in DMN area is increased during the state of boredom (Danckert & Merrifield, 2018).

The opposite to the under-load theory is an over-load theory, also known as a resource theory (Eastwood et al., 2012). This theory states that the vigilance decrease occurs with time, when vigilance on the task is required. The resource theory proposes that attention is, in fact, a function with limited resource supply. The attentional cognitive resource is a renewable entity, which can be consumed and restored. Moreover, the cognitive resources of attention act as a trade-offs during the active task engagement as well as multitasking. However, it is possible to 'train' and increase the cognitive resource capacity of attention (Randall et al., 2014). For example, according to Randall et al. the person who 'is trained' to switch tasks regularly, executing and increasing his/her attentional resources capacity, will perform. Mind-wandering can act as the mediator for restoring the necessary attentional resources (Thomson et al., 2015).

Merlo et al. (2020) used a qualitative approach to analyze mind-wandering and daydreaming episodes at work. They conducted 30 semi-structured qualitative interviews with participants of diverse occupations. Their questions used the term “daydreaming” in addition to “mind-wandering” for better clarity in communications with participants. The researchers were interested in how these mind-wandering episodes began and ended, as well as their effects on the participants. Some participants stated that they tended to fall into episodes of mind-wandering during periods of natural rest at work, or because they felt overloaded with their work and needed a break. As an outcome of the mind-wandering episodes, some participants reported that they felt refreshed after a daydreaming break and found that mind-wandering did not negatively affect their work performance; rather, they returned from their break with a “renewed ability to focus on their work” (p. 211). Although the present study does not focus directly on the impact of mind-wandering on attention paid to a work task, and evidence is based on participants’ subjective self-reflection, it provides some support for the idea that mind-wandering episodes serve as natural rest for the brain and may actually facilitate the ability to maintain attention on a subsequent task.

Further bolstering this idea of renewed ability to focus on a task after a break are two experiments that established the role of rest and task interruption on task performance (Helton & Russell, 2015). In the first experiment, participants (N = 266) performed a visuospatial vigilance task, which previously demonstrated a decrease in sustained attention after less than five minutes. Participants experienced one of three interruption conditions: the first group was given a complete rest between tasks, as well as information about the duration of the rest period; the second group worked on the primary task without interruptions; and the third group was subjected to task-switching conditions and given an alphanumeric vigilance task instead of rest. The break within the pre-interruption and post-interruption block was approximately 106 seconds long. The experiment demonstrated that performance of the post-interruption task was significantly better in the rest group compared to the continuous-task and task-switch groups.

In the second experiment, researchers added two more task-switch groups. Here, participants were given a secondary task different from the sustained attention task that required the involvement of their working memory. The results demonstrated that in complete rest conditions, participant performance of the post-interruption task increased, and reaction time decreased. For all other conditions, performance of the post-interruption task declined and reaction time increased. These findings support the theory that complete rest has a beneficial impact on task performance. The results also showed that pure rest within a high-demand task positively impacted performance. However, the researchers did not ask participants what was going on in their minds; they only suggested that during rest participants engaged in daydreaming to eliminate task monotony.

Two years later, Helton and Russell (2017) conducted a similar experiment with the same primary vigilance task but different types of secondary vigilance tasks. This time, as a secondary task to interrupt the primary vigilance task, they used verbal working memory tasks and spatial working memory tasks. The given rest period was the same as in the previous study, approximately 106 seconds. Like the previous study, the results demonstrated that in rest conditions, participants performed the post-interruption task better than did the participants in other groups. The researchers acknowledged that it is difficult to specify what type of mental activity occurs in the brain during rest—mindfulness, mind-wandering, boredom, or mindlessness—due to the lack of exact definitions. In both studies by Helton and Russell (2015; 2017), researchers controlled the type of the task during the interruption. The task they provided, verbal working memory task and spatial working memory task, while being a slightly different in its design, still were very similar in nature with the primary one. This raises a question, what if participants will switch not to another task provided by the researcher, but to any other activity, which is still recruits attentional networks, but is different from the primary task and more interesting to the participants. Will this type of interruption have the same impact on the primary task performance?

A study by Williams et al. (2018) evaluated mind-wandering as a possible mechanism of attention restoration. The authors investigated the underlying mechanism behind attentional restoration theory (ART), formulated by Kaplan and Kaplan (1989). According to this theory, exposure to the natural environment facilitates one's creative abilities by renewing the ability to direct and control attention. Kaplan and Kaplan (1989) suggested that the cognitive process at work is one of "soft fascination;" namely, an externally oriented and effortless form of attention toward a natural environment (Kaplan & Kaplan, 1989; Kaplan S. , 1995). This idea has since been re-explored, and it has been suggested that the mind-wandering that may occur during periods of exposure to a natural environment plays a key role in attentional restoration (Atchley et al., 2012). To investigate this idea and to understand the possible underlying cognitive processes of attentional restoration, Williams et al. (2018) analyzed papers on mind-wandering, ART, and creativity. They compared different aspects of cognitive processes described in ART works to mind-wandering and, based on their analysis, support the idea that mind-wandering contributes to attentional restoration. They suggest that mind-wandering can be seen as a process co-occurring with soft fascination. As cited in Kaplan and Kaplan (1989) and Williams et al (2018) describe the natural environment that facilitates soft fascination as an "invitation for the mind to wander" (p. 193). Williams et al. (2018) suggest that during an experience in nature, one's mind may go through the cycle of mind-wandering and externally oriented attention, which can contribute to attentional restoration.

Studies on the DMN, which activates during mind-wandering, also provide some support for the theorized role of mind-wandering in attention recovery. Studies show that the DMN activates not only during one's wakeful activity but also during different stages of sleep (Sämann et al., 2011; Fox et al., 2013; Christoff et al., 2016). Interestingly, a neuroimaging study by Christoff (2009) showed that mind wandering tends to recruit not only the DMN but also brain networks associated with executive functioning. Therefore, it is possible that at least some types of mind wandering may not only compete but also facilitate some attention processes by recruiting complementary brain networks (e.g., DMN) that help with processes such as attention recycling, dishabituation or mood regulation (Smallwood & Schooler, 2015). Further, sleep deprivation has been observed to hinder one's ability to maintain sustained attention when required during the day (Doran et al., 2001; Killgore, 2010; Lim & Dinges, 2008). The understanding that mind-wandering shares similar brain pathways with sleep and that sleep deprivation can result in the degradation of sustained attention leads to the idea that a lack of mind-wandering may also hinder one's ability to focus during a subsequent task.

Smartphones, Attention, and Mind Wandering

Like mind-wandering, smartphones have often been viewed as a distraction that initiates a shift in human attention (Thornton, 2014; Mendoza et al., 2018; Ward et al., 2017). For instance, studies have demonstrated that smartphone use while driving may lead to car accidents because attention is divided between the events on the road and the mobile device (Strayer et al., 2006; Lyngsie et al., 2013; Strayer & Fisher, SPIDER: A framework for understanding driver distraction, 2016). Other studies have demonstrated that students who engage in smartphone interactions while doing schoolwork, which results in multitasking, tend to have lower academic performance (Junco & Cotten, 2012). Smartphone use during lectures has been shown to have the same effect on attention; students who were distracted by a cell phone ringing during the lecture demonstrated lower results on the following test than those who maintained focus on the lecture (Shelton et al., 2009).

Similar results were found in a study by Mendoza et al. (2018), in which students were distracted by text messages on their smartphones. Kushev et al. (2016) demonstrated that smartphone notifications may cause inattention and hyperactivity symptoms associated with attention deficit hyperactivity disorder (ADHD). Thornton (2014) showed that even the mere presence of a mobile device impairs one's performance on a task. Likewise, Ward (2017) demonstrated that an individual's cognitive capacity is reduced when their smartphone is within view. However, like research on mind-wandering, most studies have examined the impact of smartphone use in relation to a task; very little is known about the impact of smartphone use during rest or idle time on one's level of mind-wandering and ability to maintain sustained attention during a subsequent task.

Some studies have put forth ideas on the relationship between mind-wandering and smartphone usage. A few studies suggest that smartphone notifications, such as calls or text messages, decrease one's performance of an ongoing task because the interruptions provoke mind-wandering and task-unrelated thoughts (Hobbiss et al., 2019). In their experimental study, Stothart et al. (2015) analyzed the performance of sustained attention to a response task (SART) of 212 undergraduate students under three different conditions: interruption by text message during the task; interruption by phone call during the task; and no interruption. The results showed that both types of smartphone notification significantly impaired the participants' task performance, even if they did not react or directly interact with their smartphones. The authors suggest that these results might be explained by mind-wandering or task-unrelated thoughts provoked by smartphone notifications. However, the participants were not asked about the mental activities that occurred after receiving a text message or call.

Further exploring this idea, Hobbiss (2019) aimed to establish the relationship between mind-wandering and external distractions, including smartphones. To accomplish this, they conducted survey research with 459 participants from different cities in the United Kingdom. The researchers interacted with participants while they were engaged in their daily activities in different locations, such as cafes, bars, shopping malls, and parks. Participants were asked how much time they spent at the exact location and what shifted their attention from the primary focus source and for how long. It was assumed that more than one distraction might occur at one time. Based on the survey results, mobile phones and mind-wandering were two of the top three most frequently reported distractions (the third was strangers). Using a hierarchical multiple regression analysis, the authors established that variations in mind-wandering can be significantly explained by distractions coming from strangers, mobile phones, and advertising. Their results support the suggestion of Stothart et al. (2015) that mind-wandering can be predicted based on exposure to external distractions, including mobile phones.

Different ideas were put forward by Markowitz (2019). These authors aimed to analyze whether one's engagement in smartphone activities impacts the time one spends in mind-wandering. In their study, 125 participants were recruited to spend six minutes in an unadorned room and were assigned to three different conditions. The first group spent the time without a smartphone; those in the second group were asked to entertain themselves with their smartphones; and members of the last group was asked to take their smartphones with them but not interact with them. After the experiment, the participants were asked to rate on a scale from 1 to 9 the extent to which their mind-wandered during the six minutes. A subsequent one-way analysis of variance (ANOVA) demonstrated that the participants who used their phones experienced significantly less mind-wandering than those who spent time without their smartphones. At the same time, no difference in mind-wandering was established between those who resisted their smartphone and the no-smartphone group. These results demonstrate that active smartphone engagement lessens the level of mind-wandering that one might experience without that active engagement.

Another study, conducted by Johannes et al. (2018), also focused on the relationship between mind-wandering and smartphone use. Unlike previous works, they focused on online vigilance, a term formulated by Klimmt et al. (2018). According to Klimmt et al. (2018) theory, online vigilance includes different types of behavior and mental processes regarding smartphone usage. The first is salience, which is the form of one's thoughts regarding their interaction with the online world, including thinking about past and future interactions. The second is reactivity, which is one's sensitivity and speed of reaction to the smartphone notification. The third is monitoring, which refers to the frequency of checking one's smartphone to follow activities in the online world.

Johannes et al. (2018) combined the different types of smartphone engagement that previous studies had considered separately. Using completed surveys from 371 responders, the researchers collected data on the participants' online vigilance, their level of daily mind-wandering (based on the Daydreaming Frequency Scale), and other parameters such as mindfulness, satisfaction with life, and affective well-being. Confirmatory analyses indicated a significant and positive correlation between online vigilance and mind wandering. Subsequent analyses of different aspects of online vigilance demonstrated that only salience is significantly related to one's level of mind wandering. This can be explained by the neural pathways involved in mind-wandering, which activate areas of the brain responsible for self-reflection, past analysis, and future prediction (Andrews-Hanna, 2012).

All studies discussed above address different aspects of the relationship between mind-wandering and smartphone interaction. However, none of them analyze the consequences of smartphone engagement on the time one might spend mind wandering and the ability to focus on a subsequent task after a rest period with a smartphone. Thus, these aspects are the focus of this work. Naturally, the aim of the current study is to investigate how smartphone use and mind-wandering differently affect the individual's attention. The proposed experiment will test the previous findings to confirm that mind-wandering during rest improves one's ability and that smartphone engagement during rest state impairs one's ability, when it comes to focusing the attention. Therefore, the following hypotheses are proposed. Firstly, it is expected that those in the mind-wandering group will show higher scores in alerting, orienting and executive control task. Secondly, the participants that are allocated to the smartphone group will perform lower scores in alerting, orienting and executive control task. Thirdly, the no-rest group will show lower scores than the two listed above groups. Fourthly, the relationship between smartphone use and mind-wandering will be addressed.

Chapter II

Method

The study was designed to address changes in attention among active smartphone users primarily. The core goal was to get a contrasting picture to scale the findings to the other population groups in future studies.

Participants

One hundred and forty-two smartphone users (97 females) participated in this study. Of these participants, 13 were excluded from the sample during the experiment; 5 were excluded due to technical issues with the software, and the other 8 failed to follow the instructions. Their exclusion resulted in final data from 129 participants (88 females). The ages ranged from 18–34 years, with a mean of 28.04 (SD = 5.23 years). Only intensive smartphone users, according to their self-reports or statistics taken from their primary smartphones, were included in the study. Daily average screen times ranged from 2 to 12 hours, with a mean of 6.08 hours (SD = 2.50). Daily average pickups, number of times that participant picks up the device in average during the day to explicitly interact with it, ranged from 60–240, with a mean of 127.19 pickups (SD = 58.18). Inclusion criteria were: (1) age range from 18–34, (2) participant considered themselves as an intensive smartphone user. Exclusion criteria were: (3) history of brain injuries or concussions during the last year; (4) history of epilepsy; (5) history of mental or psychiatric disorders, or drug or alcohol addictions; and (6) current medication that could impair the ability to focus. This data was acquired during the brief screening interview via zoom.

Before joining the study, participants were informed that the researcher was investigating the impact of smartphones on cognition among modern young people and that the study could involve boredom and time costs. They were also notified that their participation was voluntary, and that they could withdraw from the study at any time for any reason. All participants were informed that some information about the experiment was being withheld. After participating in the experiment, the participants were debriefed about the full goals and purpose of the study. All participants e-signed online consent forms before starting the experiment. This study met all the criteria for ethical research according to the American Psychological Association's (APA's) Ethical Principles of Psychologists and Code of Conduct (APA, 2016) and all the criteria established by the Belmont Report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). This study was registered under the Harvard University Human Research Protection Program (IRB code IRB21-0754).

Measures

The complexity of the research question required implementing a variety of measures that cover not only changes in attention and the extent of mind wandering during the rest and task but also the degree of involvement in smartphone interaction.

Attention Network Test

The Attention Network Test (ANT; (Fan et al., 2002)) was used as the main task of the experiment. Michael Posner designed this test to independently test three different attention networks—alerting, orienting, and executive control (Posner & Petersen, 1990)—with alerting being necessary for achieving and maintaining an alert state, orienting being involved in information selection from different sensory inputs, and executive control contributing to an individual's ability to resolve conflicts between contradictory responses (Raz, 2004). ANT combines flanker tasks with attentional and spatial cues. During the task, the participants were presented with a group of five dashes (—), or arrows pointing left or right (←, →), which randomly appeared either at the top or bottom of the computer screen. The central symbol in the arrow group was always an arrow pointing either left or right. Participants were instructed to indicate the direction of the central target arrow by pressing the corresponding arrow key on the keyboard.

The combinations of arrows and dashes represented three different flanker conditions (Figure 1). In the congruent flanker condition, all arrows, including the target arrow, pointed in the same direction; in the incongruent flanker condition, the target arrow and other arrows pointed in opposite directions; and, finally, in the neutral flanker condition, the target arrow was accompanied by dashes.

Throughout the entire task, the participants were presented with a central fixation cross (Figure 1). They were also exposed to four different types of cue conditions: a spatial cue, a double cue, a central cue represented by an asterisk (*) preceding the appearance of the line, or a no-cue condition. The spatial cue appeared at the same spot on the screen as the subsequent set of arrows, either at the top or the bottom of the screen; the central cue appeared in the center of the screen; and the double cue appeared in two locations simultaneously to inform participants that a group of arrows would appear without providing information on its location. During the no-cue condition, no cue appeared.

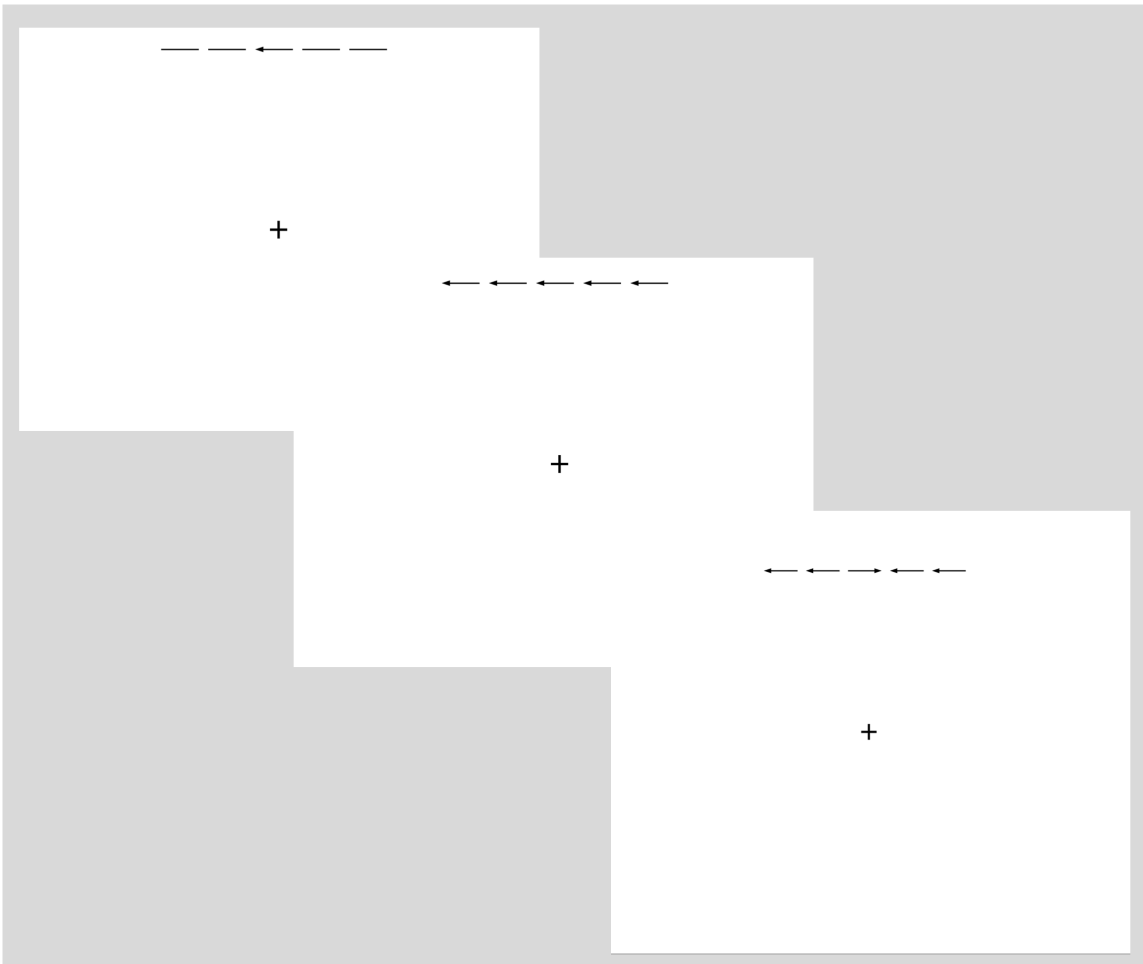


Figure 1. Examples of three different flanker conditions.

From left to right: (1) In neutral flanker condition the target arrow is accompanied with dashes; (2) In the congruent flanker condition all arrows, including the target one, point same direction; (3) In the incongruent flanker condition, the target arrow and surrounding arrows point in opposite direction.
All pictures represent the central fixation cross.

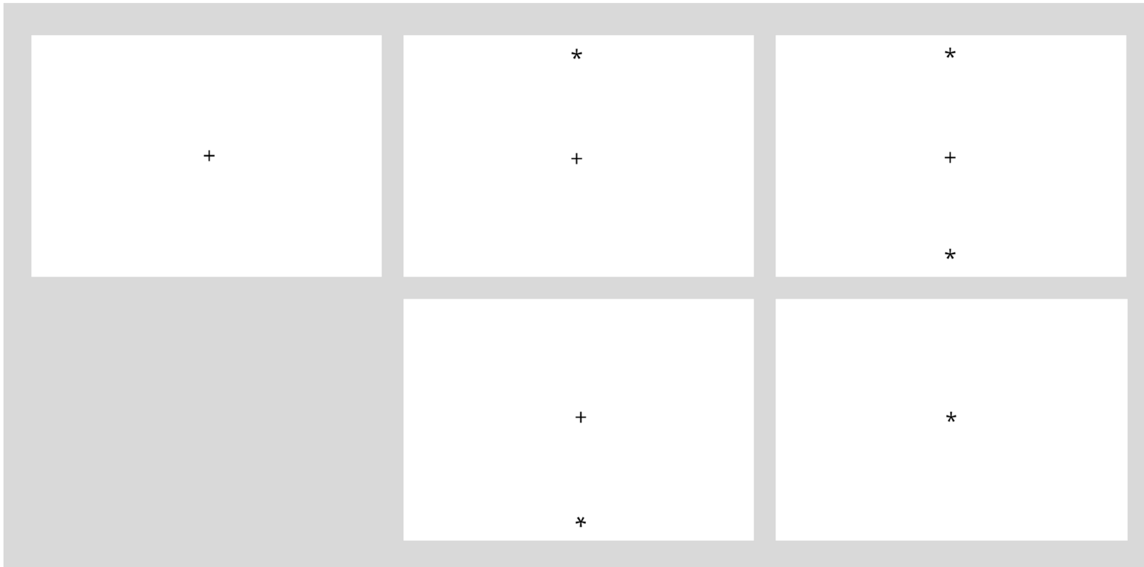


Figure 2. Four different types of cue conditions

From left to right: (1) In no-cue condition, cue does not appear on the screen. Participant is presented with the central fixation cross only; (2) At the top and at the bottom there are representation of two types of spatial-cue conditions. Appearance of the cue indicates the location of the subsequent arrows; (3) Picture in the right top corner represents the double-cue condition; two cues appear simultaneously on the opposite sides of the screen; (4) In the right bottom corner, there is an example of central cue condition; the cue appears in the middle of the screen.

For this study, the researcher used an Internet-based version of the ANT designed by the Poldrack Lab, which is based in the Department of Psychology at Stanford University, CA. Participants accessed this test at http://expfactory.org/ on their personal computers. This version comprised the following parameters: (1) a fixation cross appearing throughout the test; (2) a cue or a group of arrows or dashes appearing on the screen after a variable duration ranging from 400 to 2,700 ms, and for cue conditions, a cue appearing on the screen for 100 ms; (3) a group of arrows or dashes shown on the screen until the participant responded by pressing the key on the keyboard, with a time limit of 1,700 ms, and after the key being pressed or the 1,700 ms time limit reached, arrows or dashes disappearing and only a fixation cross being presented to the participant.

Each testing session consisted of 4 blocks: a practice session of 24 randomly presented items, during which participants were provided with feedback on whether their responses were correct or incorrect, and 3 no-feedback experimental blocks of 48 randomly presented trials per block (12 items for each cue-condition and no-cue condition x 4 items for each flanker condition). The test blocks were separated by a break screen, which was presented to the participants as a white screen with black text on it saying, “Take a break! Press any key to continue,” until they pressed any key. The length of the breaks was managed by the researcher and set at 1 min 46 s, consistent with (Helton & Russell, 2015); (Helton & Russell, 2017) studies.

Attention and task performance were assessed via the outcome measures of reaction time (RT) and error rate (ER). For calculating means for RT, only RTs for correct responses for all flanker and cue conditions were used. Error rate was calculated by diving a total number of incorrect responses for all flaker and cue conditions by total number of all responses. The effects of the three attention networks—alerting, orienting, and executive control—were calculated according to (Fan et al., 2005). For calculating the alerting effect and orienting effects, RTs for only correct responses in all types of flanker conditions were used. The alerting effect was calculated by subtracting the mean RT for the double-cue condition from the mean RT for the no-cue condition. The orienting effect was calculated by subtracting the mean RT for the spatial cue condition from the mean RT for the central cue condition. The executive control effect was calculated by subtracting the mean RT for all congruent flanking conditions (only correct responses of all types of cue-conditions) from the mean RT for the incongruent flanking conditions. The ANT and its outcomes are known to be valid and reliable measures of attention in healthy adults (Ishigami et al., 2016), with shorter RTs and lower ERs indicating better attention.

The ANT experiment lasted approximately 15 min. The participants downloaded their results to Excel spreadsheets immediately after the experiment and sent them to the researcher over Zoom. The Excel spreadsheets contained detailed information (location, duration, and type) for every appearance of the group of arrows or dashes, the cue, the fixation cross in each trial, and the main measures of RT and errors.

Mind-Wandering

After completing the ANT, to examine overall mind-wandering during breaks, participants from the rest-condition groups were asked (as in (Markowitz et al., 2019)) to rate "To what extent did you find your mind wandering during the breaks?" The answers ranged from 1 (*not at all*) to 9 (*very much*). Similarly, to examine overall mind-wandering during the task, all participants were asked to rate "To what extent did you find your mind wandering during the task?" The answers ranged from 1 (*not at all*) to 9 (*very much*).

Smartphone Usage

To understand the extent to which the participants used their smartphones, the researcher employed the Smartphone Use Questionnaire (SUQ; (Marty-Dugas et al., 2018). This self-report measure asked respondents to rate the frequency of their smartphone use. The questionnaire contained 2 groups of 10 questions. The first group of

10 questions (the Smartphone Use Questionnaire—General [SUQ-G]) assessed basic smartphone behaviors, such as how often the subjects received calls or text messages or used smartphone applications. The second set of 10 questions (the Smartphone Use Questionnaire—Absent-Minded [SUQ-A]) assessed absent-minded smartphone usage, such as how often participants engaged in smartphone activity longer than intended, or how often they found themselves unconsciously checking their smartphones. The participants responded using a seven-point Likert-type scale, ranging from 1 (*never*) to 7 (*all the time*). Higher mean scores corresponded to higher smartphone usage. Compared with other scales, this scale has the highest correlation with real smartphone usage behaviors (Ellis, 2019). This measure was used as a covariate to estimate the long-term impact of smartphone use on the ability to maintain attention (Kushlev et al., 2016), which may have impacted the results of the study.

Procedure

The experiment was conducted by the researcher individually for each participant via Zoom. The participants were required to connect to an online meeting on their own computers and bring their primary smartphones to the sessions. After providing signed consent, participants were asked to turn their cameras on and close all applications and notifications that were not relevant to the study, including websites. They were also asked to turn off and remove from their sight all other smart devices (e.g., tablets, smartwatches, and other laptops), except their primary smartphones and computers. This was necessary because the mere presence of a smart device could have deflected the participant's attention (Thornton, 2014; Ward et al., 2017).

The participants were then randomly assigned to one of three different conditions: a no-rest condition (N = 41), a smartphone rest condition (N = 42), and a mind-wandering rest condition (N = 46). Participants in the mind-wandering rest condition and the no-rest condition were also instructed to turn their primary smartphones off completely and hide them from their sight (e.g., leave them in another room).

All participants were asked to access ANT via a hyperlink and share their screen with the investigator over Zoom (see Figure 3). After reading the instructions and completing the practice section of the test, the participants in the no-rest condition were instructed to complete the ANT, skipping all breaks between test blocks by pressing any key as soon as they saw a break screen. After reading the instructions and completing the practice section of the test, participants in the smartphone rest condition were asked to entertain themselves with their smartphones during the breaks (0.105ms) between the test sections until the investigator notified them that the breaks were over, when they could continue to the next section. After reading the instructions and completing the practice section of the test, participants in the mind-wandering rest condition were instructed to let their minds wander or to daydream during the rests between the test blocks until notified that they could continue to the next section of the test. Besides the term "mind-wandering," "daydreaming" was used to ensure clearer communication with the participants, as was done by Merlo et al. (2020).

After completing the experiment, participants were asked to download their results and share them with the researcher over Zoom. Later, they answered questions about their sex, gender, age, and mind-wandering, and were asked to fill out the SUQ.

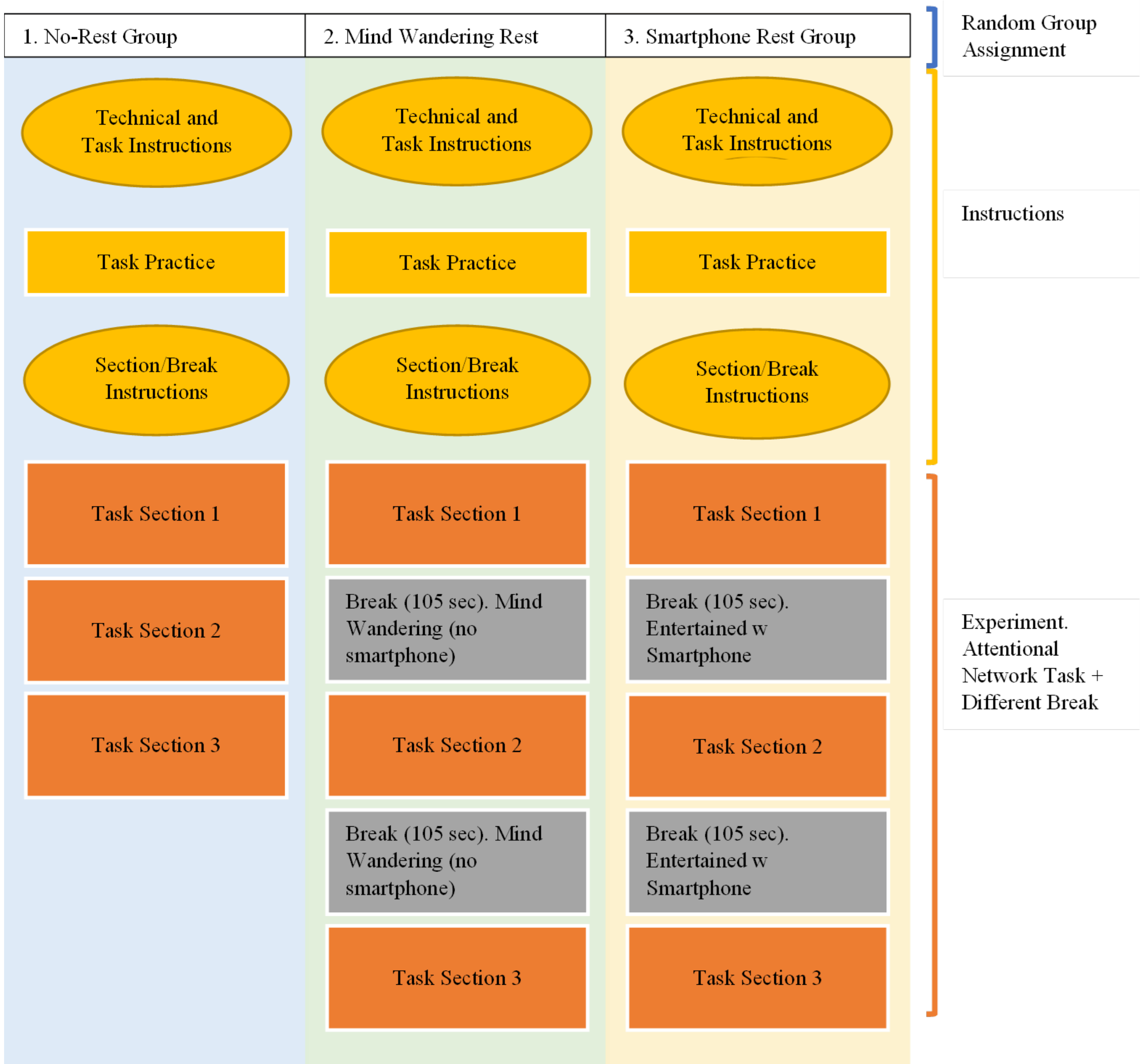


Figure 3. Represents the step-by-step study procedure.

The participants were attributed to three different conditions. In no-rest condition, participants were instructed to do the ANT skipping the break sections. In mind-wandering condition, participants were instructed to let their mind wander or daydream during the break. The third group was instructed to entertain themselves with smartphone during breaks. Break session for second and the third condition lasted for 1 minute 45 seconds.

Statistical analyses

The regression models ANOVA/ANCOVA analyses were performed for mind-wandering (table 1 & 2): The mixed ANOVA/ANCOVA (repeated measures ANOVA/ANCOVA) were executed for within-subject effects in performance and attentional networks (table 3 & 5). This is to measure if variables influence the course of performance over time per person. The scores prediction was used in order to evaluate the theoretical values of the independent variables. The levels for absent-minded SU are the possible values on the ASU scale. The scale goes from 1 to 7. However, 1 was not used, instead predicted values were from 2 to 7. The case showed at figure 3 includes: assumed average value for GUS; assumed an ASU of 2; computed the predicted values for all 3 conditions. In order to report one average value, the mean of all 3 predicted values was calculated.

Chapter III

Results

All statistical tests described below were carried out with a level of significance of $\alpha = 0.05$.

Mind-Wandering During Rest

To examine the effect of rest conditions and other variables on mind-wandering during rest, a series of ANOVA and ANCOVA models were fitted to the data. Self-reported levels of mind-wandering during rest, as the dependent variable, were entered into the model. Independent variables were entered into the model in three successive steps. Initially, only condition type was used as a predictor of whether mind-wandering differed between the conditions. Subsequently, general and absent-minded smartphone usage were entered into the model as additional predictors. In the last step, sex and age were entered into the model as additional control variables. Since the non-rest condition had no breaks between the blocks, these data were not used for the analysis, which therefore made use of a smaller sample than the other analyses reported here ($n = 87$).

Table 1 shows the model results for mind-wandering during the task. As expected, participants in the mind-wandering condition ($M = 6.60$, $SD = 2.03$) reported more mind-wandering during rest than participants in the smartphone condition: ($M = 5.86$, $SD = 2.48$), $F(1, 85) = 9.10$, $p = 0.003$, $\eta_p^2 = 0.10$. Furthermore, participants with strong absent-minded smartphone usage reported more mind-wandering during rest: $F(1, 83) = 8.94$, p

= 0.004, b = 0.72, η_p^2 = 0.10. General smartphone usage, however, showed no reliable associations with mind-wandering during rest (F[1, 83] = 1.58, p = 0.21, b = -0.49, η_p^2 = 0.02), and the same was true for sex and age (Fs < 0.76, ps > 0.38, η_p^2s < 0.01).

Table 1.

Model Results for Mind-Wandering During Rest

Model	Predictor	df1	df2	F	p	η_p^2
1	Condition	1	85	9.10	**0.003**	0.10
2	Condition	1	83	6.94	**0.01**	0.08
	General SU	1	83	1.58	0.21	0.02
	Absent-Minded SU	1	83	8.94	**0.004**	0.10
3	Condition	1	81	6.04	**0.02**	0.07
	General SU	1	81	1.28	0.26	0.02
	Absent-Minded SU	1	81	7.34	**0.01**	0.08
	Age	1	81	.76	0.59	0.004
	Sex	1	81	.30	0.39	0.01

Note: General SU = general smartphone usage (SUQ-G); Absent-Minded SU = absent-minded smartphone usage (SUQ-A).

Mind-Wandering During the Task

A similar series of ANOVA and ANCOVA models were employed to examine the effects of the rest condition and other variables on mind-wandering during the ANT. For these models, self-reported levels of mind-wandering during the task, as the dependent variable, were entered into the models. Independent variables were entered into the model in three successive steps, as in the previous analysis.

The model results for mind-wandering during the task are displayed in Table 2. The effect of the condition on mind-wandering during the task approached significance in the first model: F(2, 126) = 2.79, p = 0.07, η_p^2 = 0.04. Planned contrast testing showed that participants in the smartphone condition (M = 4.60, SD = 2.56) displayed more mind-wandering during the task than participants in the mind-wandering condition: (M = 3.52, SD = 2.08), Mdifference = 1.07, 95% CI (0.16, 1.99), p = 0.02. The findings for the mind-wandering and smartphone conditions did not differ significantly during the task compared to the non-rest condition: (M = 4.22, SD = 1.80), ps > 0.13.

Table 2.

Model Results for Mind-Wandering During the Task

Model	Predictor	df_1	df_2	*F*	*p*	η_p^2
1	Condition	2	126	2.79	0.7	0.4
2	Condition	2	124	3.20	0.04	0.05
	General SU	1	124	0.46	0.50	0.004
	Absent-minded SU	1	124	1.55	0.22	0.01
3	Condition	2	122	3.43	0.04	0.05
	General SU	1	122	0.65	0.42	0.01
	Absent-Minded SU	1	122	0.81	0.37	0.01
	Age	1	122	1.34	0.25	0.01
	Sex	1	122	0.55	0.46	0.004

Note: General SU = general smartphone usage (SUQ-G); Absent-Minded SU = absent-minded smartphone usage (SUQ-A)

With regard to the other predictors, neither general nor absent-minded smartphone usage, nor age or sex, had reliable associations with mind-wandering during the task: Fs < 1.56, ps > 0.21, η_p^2s < 0.02.

Task Performance

To investigate whether the independent variables predicted performance on ANT, the researcher employed two series of mixed ANOVAs and ANCOVAs. For these models, accuracy (ER) and RT were used as dependent variables for one series of mixed models. For each of the two dependent variables, a sequence of four mixed models was fitted to the data. The block was specified as a within-subject factor for all models. Initially, only the condition type was used as the between-subject predictor to determine whether accuracy and RT differed across conditions. Thereafter, general and absent-minded smartphone usage were entered into the model as additional between-subject predictors to test their influence. Subsequently, mind-wandering during the task was added to the model. In the last step, sex and age were entered into the model as additional control variables.

Accuracy

As shown in Table 3, the block had no effect on accuracy: $F(2, 252) = -0.96$, $p = 0.39$, $\eta_p^2 = 0.01$; there was no detectable change in ERs across the three sections of the test. The block x condition interaction was also insignificant in Model 1: $F(4, 252) = 0.73$, $p = 0.51$, $\eta_p^2 = 0.01$. Thus, the conditions did not differ regarding the ERs across the different sections of the test.

The block x absent-minded smartphone usage interaction showed a potential trend towards significance for Model 2: $F(2, 248) = 2.89$, $p = 0.06$, $\eta_p^2 = 0.02$. Inspection of the parameter estimates revealed no clear pattern for this interaction: absent-minded smartphone usage had a negligible effect on the ERs during Block 1: $b = -0.02$, $p = 0.87$, $\eta_p^2 < 0.001$. During Block 2, absent-minded smartphone usage was associated with a small decrease in ERs: $b = -0.16$, $p = 0.18$, $\eta_p^2 = 0.01$. However, during Block 3, absent-minded smartphone usage was associated with a slight non-significant increase in the ERs: $b = 0.17$, $p = 0.15$, $\eta_p^2 = 0.02$. Overall, these parameters should be interpreted with caution, since none of these effects was significant, and the omnibus test for the block x condition interaction was only marginally significant.

Furthermore, general smartphone usage had no reliable association with accuracy: $F(2, 248) = 0.16$, $p = 0.85$, $\eta_p^2 = 0.001$. Moreover, mind-wandering, sex, and gender did not show any within-subject effects: ($Fs < 1.48$, $ps > 0.23$, η_p^2s < 0.02).

Reaction Time

There was a main effect of the block on RT for Model 1: $F(1.82, 228.97) = 33.06$, $p < 0.001$, $\eta_p^2 = 0.21$. A follow-up test with repeated contrasts revealed that RTs generally decreased across conditions from Block 1 ($M = 651.89$, $SD = 84.56$) to Block 2 ($M = 633.81$, $SD = 78.54$, $F[1, 126] = 53.18$, $p < 0.001$, $\eta_p^2 = 0.30$), but not from Block 2 to Block 3 ($M = 630.10$, $SD = 77.12$, $F[1, 126] = 1.69$, $p = 0.20$, $\eta_p^2 = 0.01$).

There was a significant block x condition interaction effect observed: $F(3.63, 228.97) = 3.36$, $p = 0.01$, $\eta_p^2 = 0.05$. To follow up on this interaction, separate paired t-tests compared the task performance per block and per condition. The results of these t-tests, the differences between blocks, and the 95% confidence intervals for the effects are displayed in Table 4. Additionally, Figure 4 depicts the ERs and RTs across blocks per condition. There was a significant decrease in RTs from Block 1 to Block 2 for all conditions, as indicated by the main effect of the block (Table 3). However, only the smartphone condition showed a further decrease in RTs from Block 2 to Block 3: $t(41) = -2.36$, $p = 0.02$, $M_{difference} = -12.88$, *95% CI* (-23.90, -1.87). For the subsequent models, none of the other predictors showed any significant within-subject interactions with the block: *Fs* < 2.23, *ps* > 0.11, η_p^2s < 0.02.

Attention Networks

As for the investigation of task performance, the effects on the attention networks were examined by fitting three series of mixed models to the data—one for each attention network. Scores for alerting, orienting, and executive control were entered as dependent variables in the respective models. A sequence of four mixed models was fitted to the data. The specification of predictors was identical to that used for the analysis of task performance (see above). The findings for within-subject effects are shown in Table 5.

Alerting

Regarding the alerting network, block of the task had a marginal main effect, indicating a trend toward a general effect of the block on conditions in Model 1: $F(2, 252) = 2.85$, $p = 0.06$, $\eta_p^2 = 0.02$. Repeated contrasts revealed that alerting effect is generally decreased across conditions, from Block 1 ($M = 30.67$, $SD = 40.92$) to Block 2

(M = 40.69, SD = 41.01) (F[1, 126] = 5.17, p = 0.03, η_p^2 = 0.04), but not from Block 2 to Block 3 (M = 36.21, SD = 40.47) (F[1, 126] = 0.98, p = 0.32, η_p^2 = 0.01).

The alerting scores across blocks were by the condition, as indicated by a significant block x condition interaction. There was a significant interaction between alerting scores and condition: F(4, 252) = 3.51, p = 0.01, η_p^2 = 0.05. This significant interaction effect was also confirmed by separate paired t-tests for the attention networks. Table 6 displays the results of these t-tests and accompanying statistics. The scores for the attention networks across blocks per condition are also presented in Figure 5.

For alerting, only the smartphone condition showed significant changes across blocks, with alertness increasing from Block 1 to Block 2 (t[41] = 3.02, p = 0.004, $M_{difference}$ = 24.49, *95% CI* [8.10, 40.88]), and then decreasing from Block 2 to Block 3 (t[41] = -2.35, p = 0.02, $M_{difference}$ = -18.44, *95% CI* [-34.28, -2.60]).

The level of absent-minded smartphone usage also significantly moderated alertness scores across blocks for Model 2: F(2, 248) = 6.27, p = 0.002, η_p^2 = 0.05. The parameter estimates revealed that this interaction effect was mostly driven by absent-minded smartphone users having significantly lower values for alerting in Block 2: b = -11.61, p < 0.001, η_p^2 = 0.10. Absent-minded smartphone usage scores had no such effect during Blocks 1 and 3: *bs* < 1.27, *ps* > 0.71, η_p^2s < 0.002. The effect of absent-minded smartphone usage scores on alerting across blocks is depicted in Figure 6.

Table 3.

Within-Subject Effects for Task Performance of Block x Condition Interaction (Accuracy and RT).

		Accuracy (%)[a]				RT[b]			
Model	Predictor	*df*	*F*	*p*	η_p^2	*df*	*F*	*p*	η_p^2
1	Block	2	0.96	0.39	0.01	1.82	33.06	**< 0.001**	0.21
	Block x Condition	4	0.51	0.73	0.01	3.63	3.36	**0.01**	0.05
	Error (Block)	252				228.97			
2	Block	2	1.21	0.30	0.01	1.80	0.79	0.45	0.01
	Block x Condition	4	0.39	0.81	0.01	3.60	3.58	**0.01**	0.05
	Block x General SU	2	0.16	0.85	0.001	1.80	2.23	0.12	0.02
	Block x Absent-Minded SU	2	2.89	0.06	0.02	1.80	0.25	0.75	0.002
	Error (Block)	248				223.14			
3	Block	2	1.46	0.23	0.01	1.80	0.78	0.45	0.01
	Block x Condition	4	0.42	0.79	0.01	3.60	3.55	**0.01**	0.06
	Block x General SU	2	0.19	0.83	0.01	1.80	2.20	0.12	0.02

	Block x Absent-Minded SU	2	2.53	0.08	0.02	1.80	0.28	0.74	0.002
	Task Mind-Wandering	2	1.47	0.23	0.01	1.80	0.06	0.93	< 0.001
	Error (Block)	246				221.36			
4	Block	2	2.12	0.12	0.02	1.80	1.53	0.22	0.01
	Block x Condition	4	0.50	0.74	0.01	3.60	3.91	**0.01**	0.06
	Block x General SU	2	0.09	0.92	0.001	1.80	2.42	0.10	0.02
	Block x Absent-Minded SU	2	2.73	0.07	0.02	1.80	0.06	0.93	< 0.001
	Task Mind-Wandering	2	1.51	0.22	0.01	1.80	0.14	0.85	0.001
	Age	2	0.68	0.51	0.01	1.80	1.25	0.29	0.01
	Sex	2	0.75	0.47	0.01	1.80	1.18	0.31	0.01
	Error (Block)	242				217.97			

Note: General SU = general smartphone usage (SUQ-G); Absent-Minded SU = absent-minded smartphone usage (SUQ-A)
[a] *The assumption of sphericity held for all models.*
[b] *The assumption of sphericity was violated for all models (reported values were computed using the Greenhouse–Geisser correction).*

Table 4.

Pairwise T-Tests Comparing Pre- Versus Post-Rest Blocks (B) for Task Performance (Accuracy and RT) and the Three Conditions

							95% Confidence Interval	
Condition	N	Pre-	Post-	t	p	Mdiff	Lower	Upper
ER (%)								
Non-Rest								
B 1 vs. B 2	41	0.62	0.93	1.26	0.24	0.31	-0.19	0.82
B 2 vs. B 3	41	0.93	1.05	0.46	0.65	0.12	-0.39	0.62
Mind-Wandering								
B 1 vs. B 2	46	0.87	0.92	0.24	0.81	0.07	-0.49	0.62
B 2 vs. B 3	46	0.92	1.10	0.71	0.48	0.17	-0.31	0.65
Smartphone								
B 1 vs. B 2	42	0.77	0.75	-0.07	0.95	-0.01	-0.48	0.45
B 2 vs. B 3	42	0.75	0.71	-0.16	0.87	-0.04	-0.58	0.49
RT (ms)								
Non-Rest								
B 1 vs. B 2	41	638.94	621.92	-3.65	**0.001**	-17.01	-26.44	-7.59
B 2 vs. B 3	41	621.92	627.37	0.99	0.33	5.45	-5.70	16.60

Mind-Wandering								
B 1 vs. B 2	46	652.44	637.72	-3.40	**0.001**	-14.72	-23.43	-6.02
B 2 vs. B 3	46	637.72	634.22	-0.98	0.34	-3.50	-10.74	3.74
Smartphone								
B 1 vs. B 2	42	663.94	641.14	-5.82	**<0.001**	-22.79	-30.70	-14.88
B 2 vs. B 3	42	641.14	628.26	-2.36	**0.02**	-12.88	-23.90	-1.87

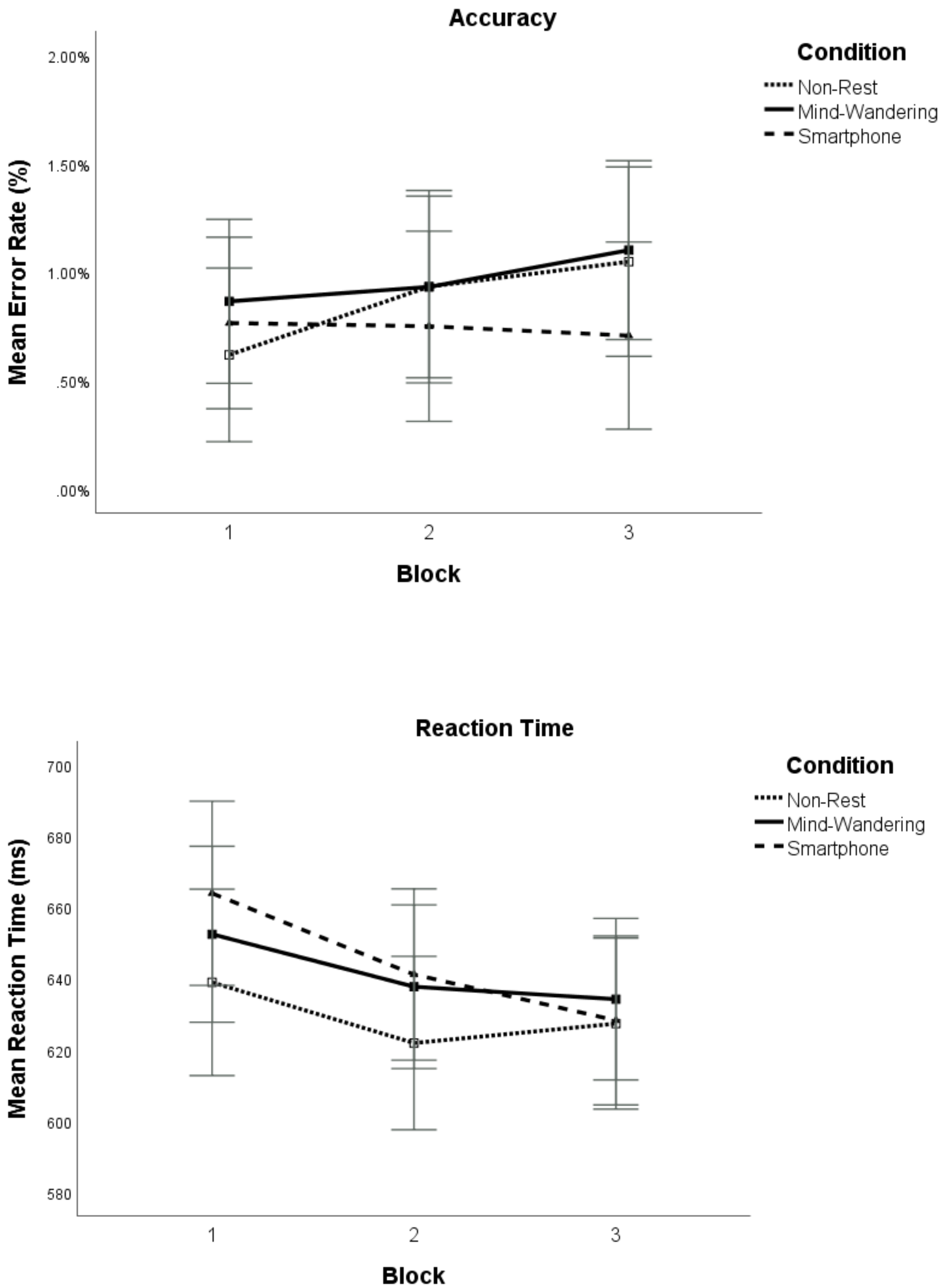


Figure 4. Performance on the ANT for the Three Conditions for the Three Blocks.

Note: Error bars are standard errors of the means.

Table 5.

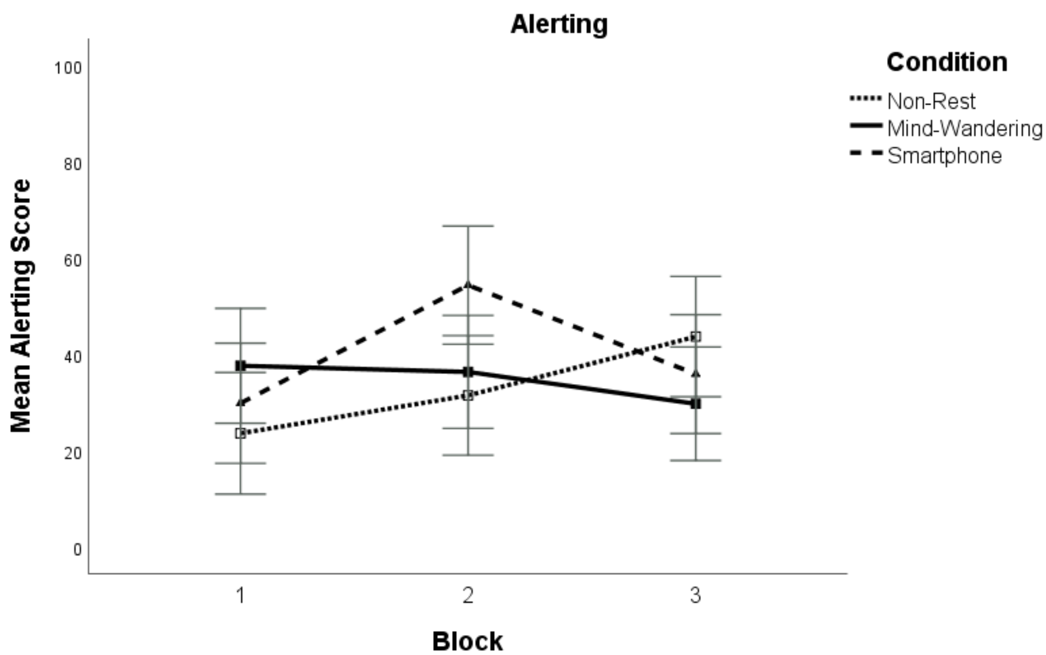
Within-Subject Effects for Attention Networks

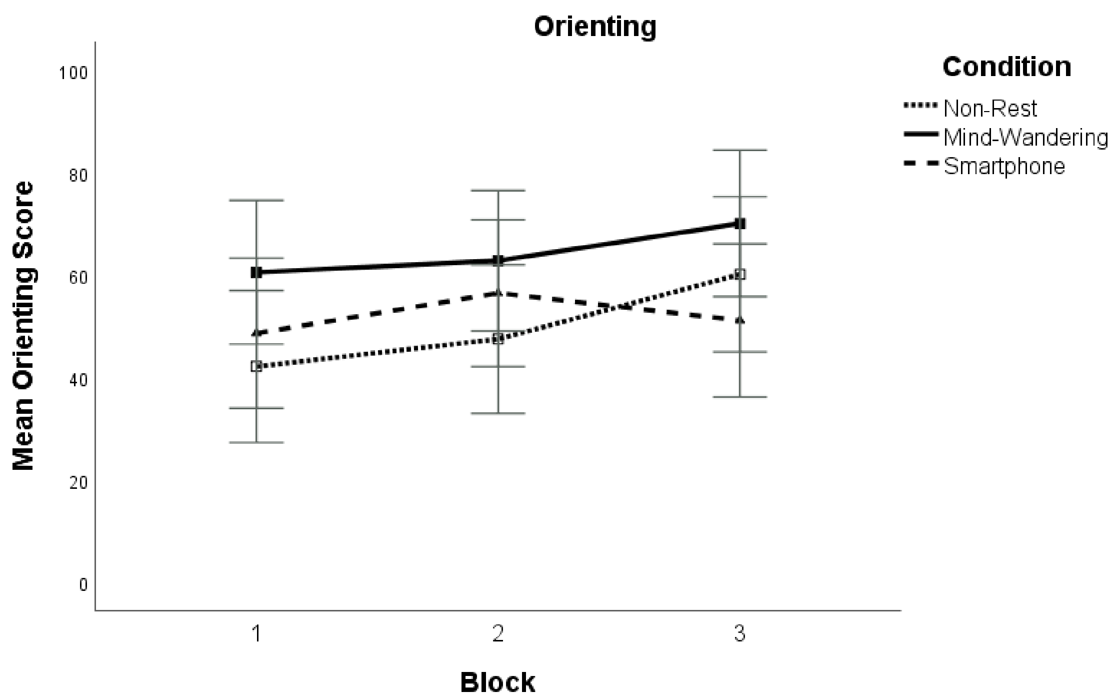
			Alerting			Orienting			Executive Control		
Model	Predictor	df	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
1	Block	2	2.85	0.06	0.02	2.28	0.10	0.02	0.27	0.77	0.002
	Block x Condition	4	3.51	**0.01**	0.05	.75	0.56	0.01	0.73	0.57	0.001
	Error (Block)	252									
2	Block	2	0.46	0.63	0.004	2.04	0.13	0.02	5.57	**0.004**	0.04
	Block x Condition	4	2.81	0.03	0.04	0.87	0.48	0.01	0.79	0.54	0.01
	Block x General SU	2	0.94	0.39	0.01	0.60	0.55	0.005	5.95	**0.003**	0.05
	Block x Absent-Minded SU	2	6.27	**0.002**	0.05	1.14	0.32	0.01	0.37	0.69	0.003

	Error (Block)	248									
3	Block	2	0.56	0.58	0.004	2.11	0.12	0.02	5.14	0.01	0.04
	Block x Condition	4	2.97	**0.02**	0.05	0.79	0.53	0.01	0.87	0.48	0.01
	Block x General SU	2	0.99	0.37	0.01	0.56	0.57	0.005	6.02	0.003	0.05
	Block x Absent-Minded SU	2	5.93	0.003	0.05	1.09	0.34	0.01	0.39	0.68	0.003
	Task Mind-Wandering	2	0.45	0.64	0.004	0.12	0.88	0.001	0.43	0.65	0.004
	Error (Block)	246									
4	Block	2	0.35	0.70	0.003	1.51	0.22	0.01	4.27	0.02	0.03
	Block x Condition	4	2.99	**0.02**	0.05	0.79	0.54	0.01	0.95	0.44	0.02
	Block x General SU	2	1.28	0.28	0.01	0.71	0.49	0.01	5.14	0.01	0.04
	Block x Absent-Minded SU	2	6.39	0.002	0.05	0.92	0.40	0.01	0.30	0.74	0.002
	Task Mind-Wandering	2	0.53	0.59	0.004	0.11	0.89	0.001	0.36	0.70	0.003
	Age	2	0.07	0.93	0.001	0.16	0.85	0.001	0.61	0.55	0.005

	Sex	2	1.00	0.37	0.01	0.78	0.46	0.01	1.01	0.37	0.01
	Error (Block)	242									

Note. The assumption of sphericity held for all models.
General SU = general smartphone usage (SUQ-G); Absent-Minded SU = absent-minded smartphone usage (SUQ-A).


Alerting
Condition
Non-Rest
Mind-Wandering
Smartphone
Mean Alerting Score
0
20
40
60
80
100
1
2
3
Block


Orienting
Condition
Non-Rest
Mind-Wandering
Smartphone
Mean Orienting Score
0
20
40
60
80
100
1
2
3
Block

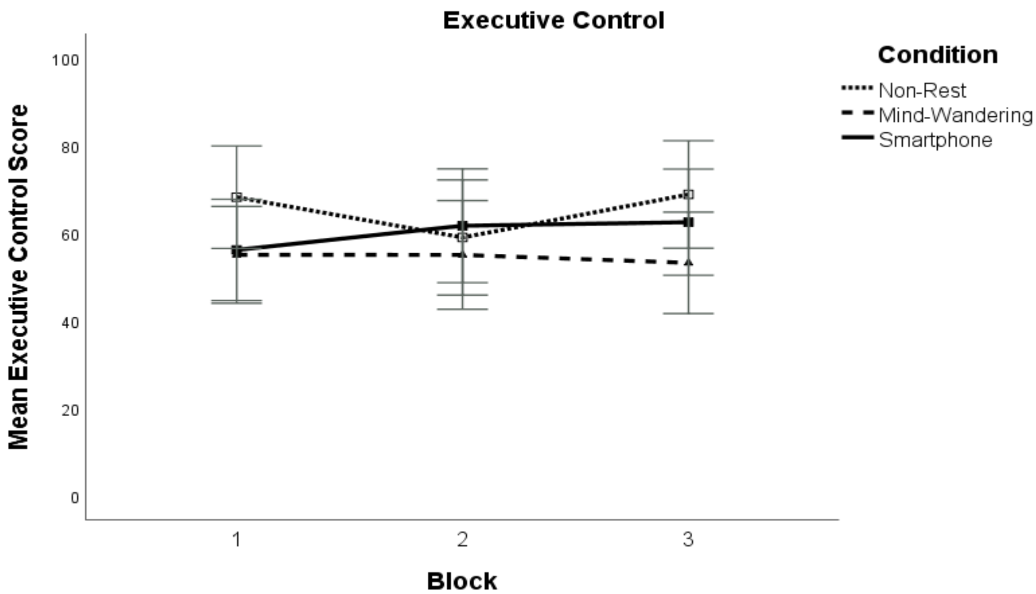


Figure 5. Attention Network Scores for the Three Conditions for the Three ANT

Orienting

There was no main effect of the block on orienting scores: $F(2, 252) = 2.28$, $p = 0.10$, $\eta_p^2 = 0.02$. The block x condition interaction was also insignificant, indicating that the condition had no effect on orienting across blocks: $F(4, 252) = 0.75$, $p = 0.56$, $\eta_p^2 = 0.01$. Similarly, none of the other predictors showed significant interaction effects with block for orienting: *Fs* < 1.15, *ps* > 0.31, η_p^2s < 0.01.

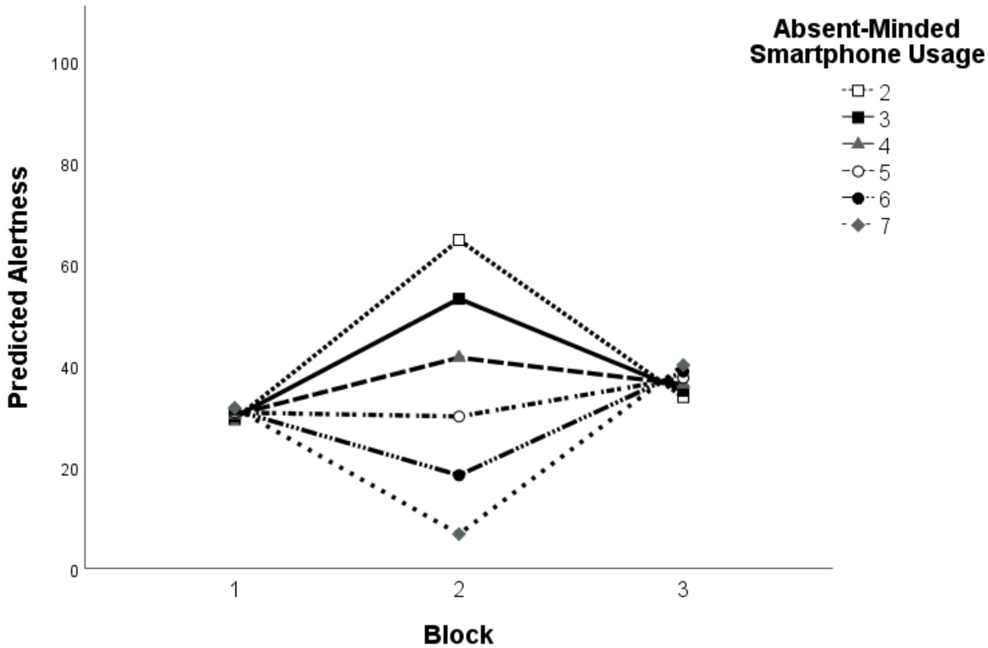


Figure 6. Predicted Alertness According to Model 2 for Scores for Absent-Minded Smartphone Usage per Block

Executive Control

Executive control was neither predicted by block (F[2, 252] = 0.27, p = 0.77, η_p^2 = 0.002), nor by a block x condition interaction in Model 1 (F[2, 252] = 0.73, p = 0.57, η_p^2 = 0.001). However, general smartphone usage significantly interacted with block in Model 2: $F(2, 248) = 5.95$, $p = 0.003$, $\eta_p^2 = 0.05$. Follow-up tests of the parameter estimates revealed that heavy smartphone users had significantly lower values for executive control during Block 2: b = -13.70, p = 0.02, η_p^2 = 0.05. This effect can be seen in Figure 7.

Smartphone usage did not predict executive control during Blocks 1 or 3 (bs < 6.90, ps > 0.19, η_p^2s < 0.01), nor did absent-minded smartphone usage have an interaction effect with block (F[2, 248] = 0.37, p = 0.69, η_p^2 = 0.003). The same was true for mind-wandering, sex, and age: Fs < 1.01, ps > 0.37, η_p^2s < 0.01.

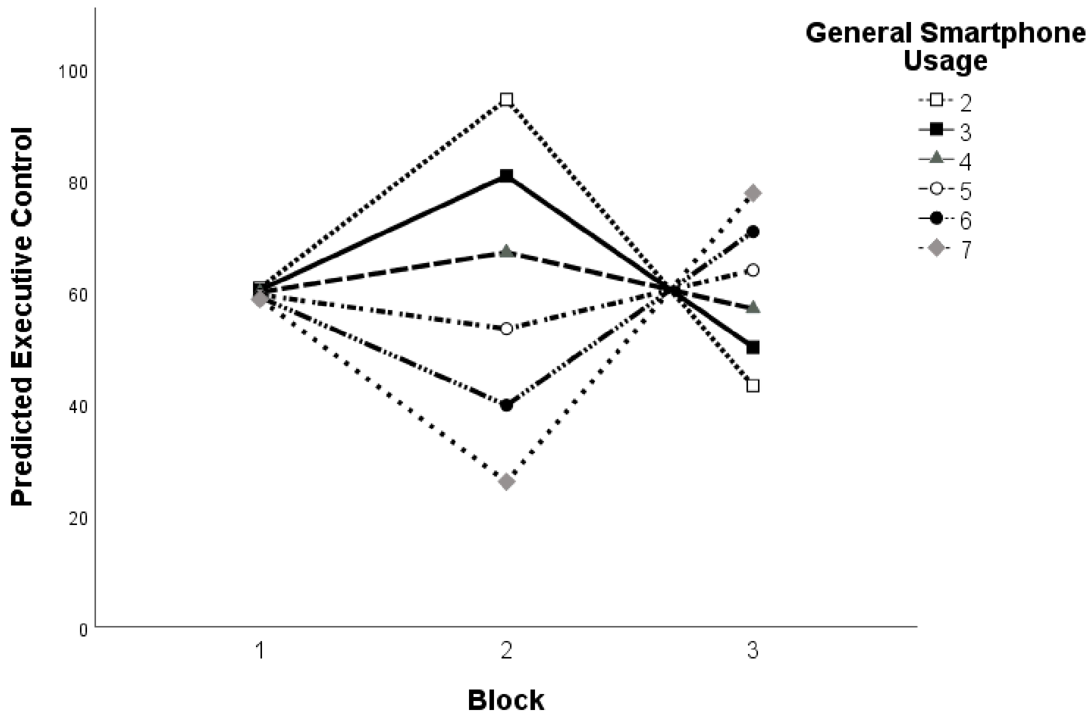


Figure 7. Predicted Executive Control According to Model 2 for Scores for Absent-Minded Smartphone Usage per Block

Table 6.

Pairwise T-Tests Comparing Pre- Versus Post-Interruption Blocks (B) for the Attention Networks and the Three Conditions

							95% Confidence Interval
Condition	N	Pre-	Post-	*t*	*p*	MDiff	Lower
Alerting							
Non-rest							
B 1 vs. B 2	41	23.64	31.51	1.12	0.27	7.87	-6.31
B 2 vs. B 3	41	31.51	43.71	2.01	0.051	12.20	-0.07
Mind-Wandering							
B 1 vs. B 2	46	37.65	36.38	-0.15	0.88	-1.27	-17.98
B 2 vs. B 3	46	36.38	29.78	-0.82	0.42	-6.60	-22.92
Smartphone							
B 1 vs. B 2	42	29.88	54.37	3.02	**0.004**	24.49	8.10
B 2 vs. B 3	42	54.37	35.93	-2.35	0.02	-18.44	-34.28
Orienting							
Non-Rest							

B 1 vs. B 2	41	42.15	47.50	0.62	0.54	5.35	-12.20
B 2 vs. B 3	41	47.50	60.14	1.95	0.06	12.64	-0.48
Mind-Wandering							
B 1 vs. B 2	46	60.52	62.79	0.29	0.77	2.27	-13.44
B 2 vs. B 3	46	62.79	70.04	0.82	0.42	7.25	-10.61
Smartphone							
B 1 vs. B 2	42	48.62	56.47	0.86	0.39	7.85	-10.57
B 2 vs. B 3	42	56.47	51.13	-0.59	0.56	-5.34	-23.58
Executive Control							
Non-Rest							
B 1 vs. B2	41	68.17	58.98	-1.36	0.18	-9.19	-22.84
B 2 vs. B 3	41	58.98	68.80	1.13	0.27	9.82	-7.80
Mind-Wandering							
B 1 vs. B 2	46	55.01	54.99	-0.003	0.998	-0.02	-12.81
B 2 vs. B 3	46	54.99	53.18	-.28	0.78	-1.81	-14.90
Smartphone							
B 1 vs. B 2	42	56.14	61.65	.87	0.39	5.51	-7.29
B 2 vs. B 3	42	61.65	62.47	.11	0.91	0.82	-13.90

Chapter IV

Discussion

The objective of this study was to understand the impact of mind-wandering during rest on one's ability to focus during the subsequent task and to test whether smartphone use during breaks, compared to mind-wandering, has a different effect on attention. First, it has been hypothesized that rest with smartphone engagement should activate salience and attentional networks, resulting in decreased activation of DMN and thus lower mind-wandering levels. Indeed, as in Markowitz et al. (2019) study, the results of our experiment demonstrated that participants who spent their rest time entertaining themselves with smartphones reported significantly lower levels of mind-wandering during rest than those in the mind-wandering rest condition.

Moreover, the participants in the mind-wandering group reported significantly lower levels of mind-wandering during the task than those who spent their breaks using smartphones. These findings support the idea that using the smartphone may trigger mind-wandering, as reported in previous studies (Stothart et al., 2015; Hobbiss et al., 2019). Indeed, mind-wandering often contains autobiographical thoughts and past- and future-related thoughts. At the same time, smartphone events, such as likes on social networks, emails, and calendar events, may trigger this type of thinking. Another more speculative explanation of the process is the idea of compensatory activation of DMN; in other words, if one will not intentionally give one's mind a break and let it wander, this may lead to mind-wandering when it is less desired—when one's attention needs to be focused on the task. However, these results are based on subjective self-reports of mind-wandering.

To estimate the actual impact of different rest conditions on attention, the changes in RT and error rates were analyzed. There was no significant effect of the rest conditions on the error rate from block to block. However, despite the non-significance of the results, it is important to note the overall trend in the error rate among the three conditions. In contrast to the mind-wandering and no-rest conditions, the smartphone rest group demonstrated a decrease in the error rate from section to section (see Figure 2). This leads to the idea that an attentional switch from the task to interacting with the smartphone may beneficially impact performance in the subsequent task. Additionally, recent studies showed that the relationship between mind wandering and attention is more complex than previously thought and may require to approach both attention and mind wandering as multi component processes (Posner & Petersen, 1990; Stawarczyk et al., 2014).

The analysis of changes in RT showed that in all rest conditions, RT decreased from the first block of the test to the second block, which means that the participants in all groups reacted faster to the target during the second section. However, surprisingly for the researcher, only the smartphone group RT significantly decreased from the second block of the task to the third block. These results contradict the initial hypothesis that smartphone usage during rest, compared to mind-wandering, should impair performance in subsequent tasks. On the contrary, smartphone engagement during breaks improved overall task performance by all measures (accuracy and RT). There is a possibility that those who spend the time in smartphones regularly are used to excessive cognitive resource, which in turn provides an advantage in completing the task employed in the current study. In other words, the smartphone takes a higher load on attention in participants and takes less attentional capacity for the task completion. Moreover, it can be explained that with time prolonged smartphone use 'trains' the cognitive resource for high-cost load turning it into low-cost. The further research is suggested to look into correlation between the two factors deeper.

In addition, this study's results contradict the outcomes of Helton and Russell (2015) work. They demonstrated that the group in the rest condition showed better performance than the group that continuously executed the location-detection task and the one that switched to the letter-detection task instead of resting. Two factors could explain this. First, while a similar rest duration of 106 seconds was implemented in both studies, in the current study, the participants were not informed about the rest period. In their work, Helton and Russell (2015) assumed that "without informing the participant, the break may itself become a vigilance task (essentially a long inter-stimulus interval)" (p. 166).

The second factor is the difference in the task-switch conditions; in their study participants in the third condition switched from a location-detection task to a letter-detection task, which are similar in nature (the same monitor, task design, and level of engagement and motivation), while in the current study, the participants switched from an attentional network test to using the personal smartphone, on which events are related to one's personal life. This difference should be addressed in further studies to understand the nature of the benefits of a switch of attention during the rest towards engaging activity on task performance.

Does it mean that switching to more engaging and self-related tasks during rest facilitates one's performance in the low-cognitive and primitive task, or is it only an effect of smartphone exposure? Interestingly, the current study findings contradict previous research (Shelton et al., 2009; Mendoza et al., 2018), in which distraction with smartphone notifications, such as text messages or smartphone calls, impaired participants' performance in their primary activity. Do only short interruptions impact the execution of the task, while intentional, complete, and prolonged interaction with the smartphone provides a sufficient amount and quality of rest and, therefore, actually increases one's performance? Alzahabi and Becker (2013) claimed that prolonged smartphone use increase motivation by providing a complete switch from the task the person performs. While it takes more resource of attentional network, it may in fact be less cognitively demanding on other domains, which are involved in mind-wandering. For example, the memory and mentalizing, which account for an internalizing cost-effective load. This may confirm the findings of the current study. This question should also be addressed in future studies.

Further investigation of the impact of different rest types on attention demonstrated that only alertness significantly decreased from the first to the second section of the test. At the same time, other attentional networks, orienting, and executive control did not differ significantly among the blocks. Additionally, the mind-wandering in the smartphone-use group could activate certain executive functions. In line with previous studies, this suggestion may provide a novel view on mind-wandering process. A similar line of results was obtained by Noone et al. (2016), claiming that mind-wandering may alter or aid the executive functioning system, rather than disrupt it. The smartphone rest condition was also the only condition with changes in alertness, with alertness scores increasing from block 1 to block 2 and then decreasing again from block 2 to 3. The small sample size can explain this. According to a preliminary, a priori analysis, 192 participants were needed to obtain significant results, while the calculations in the current experiment were based on data from 129 participants. However, overall, the significant changes in task performance from the first section to the second, but not from the second to the third block of the task, are thought-provoking. Compared to the experiments of Helton and Russell (2015; 2017), in which only two sections of the study (pre-interruption and post-interruption) were compared, the current design consisted of three sections with two breaks in between, demonstrating a decrease in the effect of the second interruption compared with the first break. This difference should be considered in further studies on the impact of rest on attention and task performance.

Finally, this study investigated the long-term impact of smartphone use on attention and task performance. First, smartphone users with higher scores in absent-minded smartphone use reported more mind-wandering during rest than users with low scores. This finding is consistent with the results of Johannes (2018), who demonstrated a positive correlation between high levels of salience in smartphone use, which may follow absent-minded patterns, and higher reported levels of mind-wandering.

However, the cause-and-effect relationship between these two parameters is unclear.

Does the tendency to fall into mind-wandering result in depressed awareness during the smartphone interaction? Does intensive smartphone usage induce more mind-wandering and compulsive smartphone use, or can this relationship be explained by other factors, such as psychological traits? The active smartphone users may in fact relief an anxiety by switching their attention to the device. The reduced anxiety has been previously linked with the better performance in attention demanding tasks (Eysenck et al., 2007). It could be speculated that the current study participants, who used smartphones before completing the second block were less anxious and could focus better on the test. In addition to previous findings, our study showed an association between absent-minded smartphone use and lower alertness scores during block 2. In contrast, general smartphone use was related to lower executive control during block 2. These findings are difficult to explain and should therefore be studied further.

The findings reported herein should be considered in the light of some limitations. Firstly, there are the existing issue with the sample size and selection technique. It was expected that the study would recruit 194 participants. However, due to the certain technical difficulties the results were obtained from 129 participants. This could impact the effect size and provide an additional challenge for statistical measurements. Moreover, the selection technique was culturally biased. This is due to the fact that those participating were coming from the same socio-economic background (SES) (Gearin et al., 2018). Furthermore, the participants in the current study were not given a proper explanation for what is mind-wandering. Instead, the instructions were to think or dream about anything. The same applies to the smartphone condition. The participants were not provided with the instruction of what is required to do with the smartphone, the instruction was to engage with any activity on the device. It can be speculated that instead of mind-wandering participants in the mind-wandering condition were actually in the state of boredom between the tasks. This could as well explain why the mind-wandering group showed lower scores when compared to smartphone group. It would be beneficial to test this assumption and to provide more concise details of the tasks in the future research.

To summarize, first, as expected, smartphone use during rest reduces the level of ongoing mind-wandering but increases the level of mind-wandering during tasks. This finding can be applied to smartphone users who experience task-unrelated thoughts or extensive mind-wandering when staying fully engaged in an activity is necessary. In fact, engaging in active MD during the task does not decrease the overall performance. In such cases, the intentional implementation of mind-wandering breaks might be helpful. Second, the central hypothesis of this study, that mind-wandering rest facilitates one's attention during the following task, while smartphone rest impairs concentration, was not confirmed. On the contrary, smartphone rest improved the participants' performance in the alerting task.

As it was previously speculated, the number of reasons may be behind this unexpected finding. The smartphone users may be better 'trained' at task switching and, therefore, require less cognitively demanding resources when performing the task. Also, it can facilitate a relief from certain task-anxiety aiding the completion of the task. The current study has a number of limitations and design flaws, which should be addressed in the future papers. The results of the study may shift the negativity bias and stigma toward smartphone use during rest. Further, it may shed a light that A cardinal switch in activity is probably the best way for the brain to recover from cognitive overload.

References

Alzahabi, R., & Becker, M. W. (2013). The association between media multitasking, task-switching, and dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance*, 39(5), 1485–1495. https://doi.org/ https://doi.org/10.1037/a0031208

Andrews-Hanna, J. R. (2012). The brain's default network and its adaptive role in internal mentation. *The Neuroscientist*, 18(3), 251–270.

Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the wild: Improving creative reasoning through immersion in natural settings. *PloS one*, 7(12), e51474.

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W., Franklin, M. S., & & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological science*, 23(10), 1117-1122.

Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., & Lerner, N. &. (2017). Detecting and quantifying mind wandering during simulated driving. *Frontiers in Human Neuroscience*, 11, 406.

Christoff, K. G. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences*, 106(21), 8719-8724. https://doi.org/https://doi.org/10.1073/pnas.0900234106

Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, 17(11), 718.

Cohen, A. O., Breiner, K., Steinberg, L., Bonnie, R. J., Scott, E. S., Taylor-Thompson, K., Rudolph, M. D., Chein, J., Richeson, J. A., Heller, A. S., Silverman, M. R., Dellarco, D. V., Fair, D. A., Galván, A., & & Casey, B. J. (2016). When is an adolescent an adult? Assessing cognitive control in emotional and nonemotional contexts. *Psychological Science*, 27(4), 549–562. https://doi.org/https://doi.org/10.1177/0956797615627625

Danckert, J., & Merrifield, C. (2018). Boredom, sustained attention and the default mode network. *Experimental brain research*, 236(9), 2507-2518. https://doi.org/ https://doi.org/10.1007/s00221-016-4617-5

Deloitte. (2018). *Global mobile consumer survey, US edition: Overview of results.* .

Doran, S. M., Van Dongen, H. P., & Dinges, D. F. (2001). Sustained attention performance during sleep deprivation: Evidence of state instability. *Archives Italiennes de Biologie*, 139(3), 253–267.

Eastwood, J. D., Frischen, A., Fenske, M. J., & Smilek, D. (2012). The unengaged mind: Defining boredom in terms of attention. *Perspectives on Psychological Science*, 7(5), 482-495.

Ellis, D. A., Davidson, B. I., Shaw, H., & & Geyer, K. (2019). Do smartphone usage scales predict behavior? *International Journal of Human-Computer Studies*, 130, 86-92.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, 7(2), 336. https://doi.org/https://doi.org/10.1037/1528-3542.7.2.336

Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage*, 26(2), 471-479.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, 14(3), 340–347. https://doi.org/ https://doi.org/10.1162/089892902317361886

Farley, J., Risko, E., & Kingstone, A. (2013). Everyday attention and lecture retention: the effects of time, fidgeting, and mind wandering. *Frontiers in psychology*, 4, 619.

Fox, K. C., Nijeboer, S., Solomonova, E., Domhoff, G. W., & Christoff, K. (2013). Dreaming as mind wandering: Evidence from functional neuroimaging and first-person content reports. *Frontiers in Human Neuroscience*, 7, 412.

Galéra, C., Orriols, L., M'Bailara, K., Laborey, M., Contrand, B., Ribéreau-Gayon, R., & ... & Maury, B. (2012). Mind wandering and driving: Responsibility case-control study. *BMJ*, 345, e8105.

Gearin, B., Fien, H., & Nelson, N. J. (2018). Mind wandering: A potentially generative idea for understanding the socioeconomic status academic achievement gap. *Translational Issues in Psychological Science*, 4(2), 138–152.

Helton, W. S., & Russell, P. N. (2015). The Rest is best: The role of rest and task interruptions on vigilance. *Cognition*, 134, 165–173. https://doi.org/https://doi.org/10.1177/0018720816683509

Helton, W. S., & Russell, P. N. (2017). Rest is still best: The role of the qualitative and quantitative load of interruptions on vigilance. *Human Factors*, 59(1), 91–100.

Hobbiss, M. H., Fairnie, J., Jafari, K., & Lavie, N. (2019). Attention, mind wandering, and mood. *Consciousness and Cognition*, 72, 1–18.

Ishigami, Y., Eskes, G., Tyndall, A., Longman, R., Drogos, L., & & Poulin, M. (2016). The attention network test-interaction (ANT-I): Reliability and validity in healthy older adults. *Experimental Brain Research*, 234(3), 815–827. https://doi.org/https://doi.org/10.1007/s00221-015-4493-4

Johannes, N., Veling, H., Dora, J., Meier, A., Reinecke, L., & & Buijzen, M. (2018). Mind-wandering and mindfulness as mediators of the relationship between online vigilance and well-being. *Cyberpsychology, Behavior, and Social Networking*, 21(12), 761–767.

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education*, 59(2), 505–514.

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective. *Cambridge University Press, Cambridge (1989)*.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15(3), 169–182.

Killgore, W. D. (2010). Effects of sleep deprivation on cognition. *Progress in Brain Research*, 185, 105–129. https://doi.org/https://doi.org/10. 1016/B978-0-444-53702-7.00007-5

Klimmt, C., Hefner, D., Reinecke, L., Rieger, D., & & Vorderer, P. (2018). The permanently online and permanently connected mind. Mapping the cognitive structures behind mobile Internet use. *In P. Vorderer, D. Hefner, L. Reinecke & C. Klimmt (Eds.), Permanently online, permanently connected. Living and communication in a POPC world.*, pp. 18-28.

Kushlev, K., Proulx, J., & Dunn, E. W. (2016). Silence your phones: Smartphone notifications increase inattention and hyperactivity symptoms. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pp. 1011.

Lim, J., & Dinges, D. F. (2008). Sleep deprivation and vigilant attention. *Annals of the New York Academy of Sciences*, 1129(1), 305–322.

Lyngsie, K., Pedersen, M. S., Stage, J., & Vestergaard, K. F. (2013). Don’t text while driving: The effect of smartphone text messaging on road safety during simulated driving. *IFIP Conference on Human–Computer Interaction*, pp. 546–563.

Maillet, D., Beaty, R. E., Jordano, M. L., Touron, D. R., Adnan, A., Silvia, P. J., Kwapil, T. R., Turner, G. R., & Spreng, R. N. (2018). Age-related differences in mind-wandering in daily life. *Psychology and Aging*, 33(4), 643–653. https://doi.org/https://psycnet.apa.org/doi/10.1037/pag0000260

Markowitz, D. M., Hancock, J. T., Bailenson, J. N., & Reeves, B. (2019). Psychological and physiological effects of applying self-control to the mobile phone. *PLOS One*, 14(11), e0224464. https://doi.org/https://doi.org/10.1371/journal.pone.0224464

Marty-Dugas, J., Ralph, B. C., Oakman, J. M., & & Smilek, D. (2018). The relation between smartphone use and everyday inattention. *Psychology of Consciousness: Theory, Research, and Practice*, 5(1), 46–62. https://doi.org/ https://doi.org/10.1037/cns0000131

Mendoza, J. S., Pody, B. C., Lee, S. K., & McDonough, I. M. (2018). The effect of cellphones on attention and learning: The influences of time, distraction, and nomophobia. *Computers in Human Behavior*, 86, 52–60.

Merlo, K. L., Wiegand, K. E., Shaughnessy, S. P., Kuykendall, L. E., & Weiss, H. M. (2020). A qualitative study of daydreaming episodes at work. *Journal of Business and Psychology*, 35(2), 203–222. https://doi.org/https://doi.org/10.1007/s10869-018-9611-4

Murray, S., Krasich, K., Schooler, J. W., & Seli, P. (2020). What's in a task? Complications in the study of the task-unrelated-thought variety of mind wandering. *Perspectives on Psychological Science*, 15(3), 572-588.

Nielsen. (2019). *The Nielsen total audience report: Q3 2018.*

Noone, C., Bunting, B., & Hogan, M. J. (2016). Does mindfulness enhance critical thinking? Evidence for the mediating effects of executive functioning in the relationship between mindfulness and critical thinking. *Frontiers in psychology*, 6, 2043. https://doi.org/https://doi.org/10.3389/fpsyg.2015.02043

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, 13, 25–42. https://doi.org/https://doi.org/10.1146/annurev.ne.13.030190.000325

Raichle, M. E. (2015). The brain's default mode network. *Annual review of neuroscience* , 38, 433-447.

Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: a theory-driven meta-analysis of attention regulation. *Psychological bulletin*, 140(6), 1411.

Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin*, 140(6), 1411–1431. https://doi.org/https://doi.org/10.1037/a0037428

Raz, A. (2004). Anatomy of attentional networks. *The Anatomical Record Part B: The New Anatomist: An Official Publication of the American Association of Anatomists*, 281(1), 21-36.

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology*, 26(2), 234–242.

Sämann, P. G., Wehrle, R., Hoehn, D., Spoormaker, V. I., Peters, H., Tully, C., Holsboer, F., & & Czisch, M. (2011). Development of the brain's default mode network from wakefulness to slow wave sleep. *Cerebral cortex*, 21(9), 2082-2093.

Shelton, J. T., Elliott, E. M., Eaves, S. D., & Exner, A. L. (2009). The distracting effects of a ringing cell phone: An investigation of the laboratory and the classroom setting. *Journal of Environmental Psychology*, 29(4), 513–521.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, 132(6), 946.

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: empirically navigating the stream of consciousness. *Annual review of psychology*, 66, 487-518.

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review*, 14(3), 527–533.

Smith, A. (2019). *U.S. smartphone use in 2015.* Pew Research Organization.

Stawarczyk, D., Majerus, S., Catale, C., & D'Argembeau, A. (2014). Relationships between mind-wandering and attentional control abilities in young adults and adolescents. *Acta Psychologica*, 148, 25–36. https://doi.org/https://doi.org/10.1016/j.actpsy.2014.01.007

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.

Strayer, D. L., & Fisher, D. L. (2016). SPIDER: A framework for understanding driver distraction. *Human Factors*, 58(1), 5–12.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Human Factors*, 48(2), 381–391.

Thomson, D. R., Besner, D., & Smilek, D. (2015). A resource-control account of sustained attention: Evidence from mind-wandering and vigilance paradigms. *Perspectives on psychological science*, 10(1), 82-96. https://doi.org/https://doi.org/10.1177/1745691614556681

Thomson, D. R., Seli, P., Besner, D., & Smilek, D. (2014). On the link between mind wandering and task performance over time. *Consciousness and Cognition*, 27, 14–26.

Thornton, B. F. (2014). The mere presence of a cell phone may be distracting. *Social Psychology*, 45, 479–488.

Unsworth, N., & Robison, M. K. (2018). Tracking arousal state and mind wandering with pupillometry. *Cognitive, Affective, & Behavioral Neuroscience*, 18(4), 638-664.

Wammes, J. D. (2016). Mind wandering during lectures I: Changes in rates across an entire semester. *Scholarship of Teaching and Learning in Psychology*, 2(1), 13.

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.

Williams, K. J., Lee, K. E., Hartig, T., Sargent, L. D., Williams, N. S., & & Johnson, K. A. (2018). Conceptualising creativity benefits of nature experience: Attention restoration and mind wandering as complementary processes. *Journal of Environmental Psychology*, 59, 36–45.

Yanko, M. R., & Spalek, T. M. (2014). Driving with the wandering mind: The effect that mind-wandering has on driving performance. *Human Factors*, 56(2), 260–269.