Does a smartphone on the desk drain our brain? No evidence of cognitive costs due to smartphone presence in a short-term and prospective memory task

Matthias Hartmann[1,2], Corinna S. Martarelli[1], Thomas P. Reber[1], and Nicolas Rothen[1]

[1] Faculty of Psychology, Swiss Distance University Institute, Brig, Switzerland

[2] Department of Psychology, University of Bern, Bern, Switzerland

Correspondence concerning this article should be addressed to: Matthias Hartmann, Faculty of Psychology, Swiss Distance University Institute, Überlandstrasse 12, 3900 Brig, Switzerland; matthias.hartmann@fernuni.ch

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Abstract

It has recently been shown that the mere presence of one's own smartphone on the desk impairs working memory performance. The aim of this study was to follow up on this important finding by assessing the effect of smartphone presence (present on the desk vs. absent from the desk) on different memory functions (short-term memory and prospective memory), and by further examining the moderating role of individual differences in smartphone dependency and impulsiveness. We found no overall effect of smartphone presence on short-term and prospective memory performance. There was a moderating effect for prospective memory: Performance was better when the smartphone was absent versus present for participants with low smartphone dependency. In light of the absence of an overall effect of smartphone presence on memory functions, our results show that previous findings of impairments in working memory due to smartphone presence do not generalize to other domains of memory capacity.

Keywords: smartphone, smartphone addiction, smartphone dependency, attention, short-term memory, prospective memory, impulsiveness, delay discounting

1. Introduction

During visual perception, our action systems are automatically activated by the action opportunities, or "affordances", provided by perceived objects (e.g., Gibson, 1979; Grèzes, Tucker, Armony, Ellis, & Passingham, 2003; Tucker & Ellis, 1998). Affordance effects hold true particularly for graspable and familiar objects (Bellebaum et al., 2013; Netelenbos & Gonzalez, 2015), suggesting that personally interacting with objects influences the amount of attention that our cognitive system devotes to those objects in our environment (Ambrosini & Costantini, 2017). One object with which we have come to interact with more and more over the last decades is our smartphone. Nowadays, especially in developed countries, virtually all adults own a smartphone and have numerous daily interactions with it (e.g., Haug et al., 2015; Willemse et al., 2014). Smartphones have become ubiquitous. Increasing mobile network coverage allows us to be constantly plugged into the digital world, as well as to access information, social networks, and entertainment (e.g., music, movies, games) at any moment. A smartphone thus allows for a vast range of interactions with the environment that would otherwise be outside of the scope of our effector system (Bach, Nicholson, & Hudson, 2014). For these reasons, strong affordances can emerge from a smartphone and, together with its high personal relevance for many individuals (Haug et al., 2015; Randler et al., 2016), make the smartphone an extremely salient object in our environment that constantly captures our attention. The aim of the current study was to further investigate the impact of the presence of one's own smartphone on cognitive processes.

Although there is no doubt that smartphones facilitate many daily activities, help to maintain or enhance personal relationships, and have the potential to increase our well-being (e.g., Bain, Jones, O'Brian, & Lipman, 2015; Glynn et al., 2014; Gustafson et al., 2014; Lane, 2011; Lui, Marcus, & Barry, 2017), it is also important to consider their potentially negative effects. Given that smartphones provide endless opportunities for interacting with them (e.g., there is always something to check online), cognitive effort is required to suppress the urge to use the smartphone or, in other words, to resist the various affordances offered by smartphones. If people fail to exercise cognitive control, their smartphone usage can become maladaptive, leading to smartphone use in situations where it is more advisable to focus on (offline) real-life activities, such as talking with friends, learning or working. If people are using their smartphone during their working time for non-working-related purposes (e.g., social networking, checking news), it is no surprise that the distraction impairs work performance, eventually resulting in a reduced gross domestic product (GDP).

People might not only be distracted by their smartphones when they are using them, but also when the smartphone is simply present in their surroundings (Stothart, Mitchum, & Yehnert, 2015; Thornton, Faires, Robbins, & Rollins, 2014; Ward, Duke, Gneezy, & Bos, 2017). For example, Stothart et al. (2015) found that seeing a message notification on one's smartphone decreases performance in an ongoing task, even when the individual is not responding to or interacting with the smartphone at that moment. The authors attributed this 'attentional cost' to task-irrelevant thoughts concerning the source or content of the message triggered by the notification. Even more surprising, Ward et al. (2017) recently found that performance in a working memory task (Automated Operation Span; OSpan; Unsworth, Heitz, Schrock, & Engle, 2005) and in a task measuring fluid intelligence (Raven's Standard Progressive Matrices, RSPM; Raven, Raven, & Court, 1998) was lower when a smartphone (either on silent mode or switched off) was placed on the desk in front of the participants compared to when it was placed in another room, with intermediate performance when the smartphone was close to the participants but out of sight (i.e., in their pockets/bags). The tasks used in Ward et al.'s study (OSpan and RSPM) are sensitive to the current availability of attentional resources (Engle, Cantor, & Carullo, 1992; Mani, Mullainathan, Shafir, & Zhao, 2013; Turner & Engle, 1989). These results therefore suggest that a smartphone, as soon as it is in sight or close to the owner (even if it is not in use), automatically captures attention and engages cognitive resources, either due to thoughts related to the smartphone use (e.g., social networks, news) or due to the inhibition of these distracting thoughts (Clapp, Rubens, & Gazzaley, 2010; Roye, Jacobsen, & Schröger, 2007; Thornton et al., 2014; Ward et al., 2017). Since cognitive resources are limited, the attentional resources absorbed by the smartphone consequently lead to a reduced performance in the primary task at hand (Thornton et al., 2014; Ward et al., 2017). Ward et al. (2017) also found that the cognitive costs induced by smartphone presence were amplified for people scoring high on a smartphone dependency measure, possibly because the smartphone is even more important and its presence more distracting.

Since many people put their smartphones on their desk during work and have no awareness of its subtle and potentially negative effect on work performance, (Ward et al., 2017), the findings put forth by Ward et al. (2017) are highly relevant for society (e.g., optimizing of working environment, GDP). The aim of this study was therefore to extend these important results and to further explore the underlying mechanisms of the cognitive costs associated with smartphone presence. Specifically, we assessed the generalizability of the results by Ward et al. (2017) by employing a conceptually similar, but not identical, task that allows for several critical extensions of the original findings. In the working memory task used in Ward et al. (2017), participants had to maintain a sequence of letters in working memory while they performed mental arithmetic as a distractor. In our task, participants had to encode and maintain the semantic content of images while they read out loud irrelevant words as a distractor. These tasks are conceptually similar since both involve the maintenance and updating of information in working memory while simultaneously processing unrelated information. Both tasks thus require attentional resources and involve controlling and regulating cognitive processes that are crucial for the maintenance of information in working memory (Baddeley, 2003; Baddeley & Hitch, 1974; Barrouillet, Camos, & Camos, 2014; Cowan, 2010; Unsworth & Engle, 2007). Since both tasks are demanding and bring participants to the limits of their cognitive capacities, we expected that our task would also be sensitive to the cognitive costs associated with smartphone presence (Clapp et al., 2010; Thornton et al., 2014; Ward et al., 2017).

Despite these conceptual similarities, our task has a slightly different focus. Specifically, the phase of high cognitive load (induced by the processing of irrelevant information) coincided with the encoding and immediate short-term storage of the relevant information, and to a lesser extent to the rehearsal and manipulation of the stored information as in Ward et al.'s (2017) task (see Discussion section for a more specific discussion about the task differences). In order to emphasize this point, we use the term "complex short-term memory task" (Meier, von Wartburg, Matter, Rothen, & Reber, 2011; Meier, Zimmermann, & Perrig, 2006; Rothen & Meier, 2014). In addition to the new focus on short-term memory storage, we manipulated several variables that might be relevant for the negative effect of smartphone presence, allowing to better understand the underlying mechanisms. A case in point is task difficulty, which was manipulated by varying the number of to-be remembered items. Given the assumption of limited attentional resources during difficult tasks, the effect of smartphone presence should be more pronounced when the task is more difficult. Thus, we expected an interaction between smartphone presence and task difficulty. Another variable of interest is semantic relatedness. In some trials, the distractor words consisted of a smartphone-related word (e.g., cellphone). Based on the theory of spreading activation in semantic networks (e.g., Anderson & Pirolli, 1984), we assumed that processing an item semantically related to the word 'smartphone' would activate the concept of smartphone and increase the saliency of the smartphone on the desk, which in turn would increase cognitive costs. Thus, we also expected an interaction between smartphone presence and item relatedness (smartphone-related vs. smartphone-unrelated items).

We further assessed the generalizability of the results reported by Ward et al. (Ward et al., 2017) by measuring the effect of smartphone presence on a different memory domain: prospective memory. Prospective memory is the ability to remember to perform a planned action or recall a planned intention at a future point in time on a self-initiated basis (McDaniel & Einstein, 2007), such as remembering to answer an email later in the day, posting a letter on the way home, or taking a medication before going to bed. Given that a smartphone is often present in situations where intended actions would be recalled (e.g., during work, on the way home, or before going to bed), a negative effect of smartphone presence on prospective memory would have additional critical consequences for everyday life. In order to assess a possible negative effect of smartphone presence on prospective memory, we included a prospective memory cue in the complex short-term memory task (see Rothen & Meier, 2014).

The final aspect in which we aimed to extend the findings by Ward et al. (2017) was by taking a closer look at personality variables that possibly moderate the effect of smartphone presence on cognitive performance. In the present study, we used the same scale as Ward et al. (2017) but also the smartphone addiction scale (SAS) as an established measurement for smartphone dependency (Haug et al., 2015; Kwon, Kim, Cho, & Yang, 2013; Kwon, Lee, et al., 2013). In addition, we assessed impulsiveness as another possible moderator variable. We focused on impulsiveness because impulsive behavior, among others, is associated with an impaired ability to suppress impulses (e.g., Ainslie, 1975; H. J. Eysenck, 1993; Whiteside, Lynam, Miller, & Reynolds, 2005), which is important for inhibiting the temptation to use one's smartphone. We therefore hypothesized that a negative effect of smartphone presence would be more pronounced for people with higher levels of individual impulsiveness.

In sum, this study provides the first, to the best of our knowledge, conceptual replication and extension of the striking and relevant findings of a negative effect of the mere presence of a smartphone on cognitive performance (Ward et al., 2017). The hypotheses, methods and analyses for this study were preregistered on OSF (https://osf.io/6cd5f).

2. Materials and Methods

2.1 Participants

A total of 302 participants completed the study (mean age = 22.4, ranging from 17 – 44, 205 female). All participants gave their written informed consent prior to the study. The study protocol was approved by the Ethics Committee of the Human Sciences Faculty of the University of Bern.

The sample size was based on Ward et al.'s results (2017). In their study, the effect sizes were 0.46 in Experiment 1, and 0.64 in Experiment 2 when comparing smartphone presence versus absence conditions in the OSpan task. We therefore expected a medium effect size, requiring at least 105 participants per condition (smartphone present vs. absent) with input parameters: d = .5, alpha = .05, 1 - beta = .95 for an independent sample *t*-test (a priori G*Power analysis; Faul, Erdfelder, Lang, & Buchner, 2007). We initially recruited 320 participants (see preregistration), but 18 datasets were lost or incomplete due to technical problems. Our final sample consisted of 302 participants (151 for the smartphone present, and 151 for the smartphone absent condition).

2.2 Material

The code and stimulus material from the complex short-term memory task inclusive prospective memory task can be downloaded from OSF (https://osf.io/6cd5f) [will be available upon acceptance of the manuscript].

2.2.1 Complex Short-term Memory Task

The task stimuli consisted of 155 word-picture pairs (also referred to as items). One-hundred-and-forty words were randomly selected from the handbook of German word norms (Hager & Hasselhorn, 1994). An additional set of words consisted of 15 words associated with smartphone, such as "touchscreen", "SIM card", or "call". The frequency of all words was calculated on the basis of the Leipzig Corpora Collection (www.corpora.uni-leipzig.de; webcrawl database: 3 million words from German news 2015). The pictures were selected from the Bank of Standardized Stimuli (BOSS; Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010) based on the criteria that the depicted objects were immediately recognizable and easy to name (see Rothen & Meier, 2014), and not associated with a smartphone. Words and pictures were randomly paired and distributed to 30 blocks (6 blocks with 3, 4, 5, 6, or 7 items). Two additional blocks with two and three items were used as practice trials (5 out of the 155 word-picture pairs).

Half of the blocks (15) contained a smartphone-related word. Each of those blocks had a corresponding control block (i.e., a block without a smartphone-related word but with a filler word that matched the corresponding smartphone-related word in terms of frequency and word length). The blocks were presented in pseudorandomized order so that half of the blocks with a smartphone-related word belonged to the first half, and the other half to the second half of the task. In order to control for potential effects of context and block order, there was a second pseudorandomized order of the blocks in which also the smartphone-related words were exchanged with the matched filler words of the corresponding blocks.

2.2.2 Prospective Memory Task

The prospective memory task was induced by instructing participants to inform the experimenter as soon as they saw a word from the category of musical instruments. The word "trumpet" was used as prospective memory cue, which was always presented in the last block (Block 30, 6th position) of the complex short-term memory task.

At the end of the experiment, three control questions were asked in order to assess prospective memory performance in the form of Yes/No responses: (1) "After the first part of the task, you have been instructed to do something under particular circumstances. Do you remember what you were supposed to do?"; (2) "Do you remember that you were supposed to do something when you see a word of a particular category"; (3) "Do you remember what you were supposed to do when you see a word from the category of musical instruments?". For yes responses, participants were asked to indicate the action they were supposed to do in order to validate their response. These questions ensure that participants who failed in the prospective memory task did so because of the prospective (i.e., noticing the cue) rather than the retrospective (i.e., forgetting what the target category was) part of the task.

2.2.3 Raven's Standard Progressive Matrices (RSPM)

The RSPM was used as a 10 minutes distractor task (delay) between the instruction of the prospective memory task and the start of the second half of the complex short-term memory task. We used the same 10 matrices that were also used in Ward et al. (Ward et al., 2017) (D2, D4, D6, D8, D10, D12, E1, E2, E4, E6). We initially also planned to analyze the performance in the distractor task in order to replicate the effect of smartphone presence on fluid intelligence (Ward et al., (Ward et al., 2017); see preregistration). However, these data were not registered properly due to technical problems (some trials ended before the predefined time elapsed and thus sometimes before a response was entered). Thus, we were not able to analyze these data.

2.2.4 Smartphone Dependency

Smartphone dependency was assessed by means of the same scale as used in Ward et al.'s study (2017) and by means of the widely used smartphone addiction scale (SAS; Kwon, Kim, et al., 2013; Kwon, Lee, et al., 2013). The former contained six items such as "It would be painful for me to give up my cell phone for a day" or "It drives me crazy when my cell phone runs out of battery", and participants indicated their level of agreement on a 7 point Likert scale (ranging from strongly disagree to strongly agree). For the SAS, we used a German short version (SAS-SV) validated by Haug et al. (2015) including 10 items (e.g., "Having a hard time concentrating in class, while doing assignments, or while working due to smartphone use") and employing a 6 point Likert scale (ranging from strongly disagree to strongly agree).

2.2.5 Impulsiveness

Impulsiveness is a multidimensional construct that includes several characteristic behaviors such as difficulty in controlling impulses, acting without careful thinking, the tendency to prefer an immediate smaller reward over a larger delayed reward, seeking novel and exciting experiences, as well as the tendency to choose risky options (S. B. Eysenck & Eysenck, 1977; Patton, Stanford, & Barratt, 1995; Perales, Verdejo-García, Moya, Lozano, & Pérez-García, 2009; Reynolds, Ortengren, Richards, & de Wit, 2006). We assessed these different aspects of impulsiveness with a German version of the Brief Impulsive Behavior Scale (Kovaleva, Beierlein, Kemper, & Rammstedt, 2012), which is based on the four factors urgency, premeditation, perseverance, and sensation seeking (UPPS; Whiteside & Lynam, 2001; Whiteside et al., 2005), and by applying a short task that assessed the delay discounting rate (Koffarnus & Bickel, 2014) based on 15 discrete discounting choices.

2.3 Apparatus and Experimental Setting

The experiment was run on an ordinary laptop. Demographic questions, questionnaires, and the distractor task (RSPM) were assessed using the open source survey tool Limesurvey (www.limesurvey.org). The complex short-term memory task, the prospective memory task, and the delay discounting task were programmed in PsychoPy3 (Peirce, 2007); the former was exported to JAVA and uploaded to the pavlovia hosting server (www.pavlovia.org). The experiments were conducted by 20 different experimenters that were all trained with the experimental procedure by the authors N. R. and M. H. Due to logistic reasons, the different experimenters used different rooms for testing. All rooms provided enough space to place the smartphone clearly out of the peripersonal space (out of reach and view) of the participants in the smartphone absent condition.

2.4 Procedure

At the beginning of the study, the experimenter asked participants to put their smartphones in flight mode (as per standard experimental protocol), thus requiring them to take their smartphones out of their bags/pockets. In the *smartphone present* condition, the experimenter instructed the participants to put the smartphone on the desk (next to the laptop), with the remark that they would need it for a later task. In the *smartphone absent* condition, the experimenter asked the participants to hand him/her the smartphone (after participants put it into flight mode) and the experimenter then put it on the opposite side of the room away from participants, with the justification that this would hinder distraction. It is not uncommon that participants are separated from their smartphones when participating in psychological experiments. Participants then signed the informed consent form and started the experimental procedure on the laptop. After they had entered their demographic data (age, gender) into Limesurvey, they started with the first part of the complex short-term memory task. They were told that they would be presented with a series of words and pictures that would appear simultaneously on the screen. They were instructed to read each word aloud and memorize the picture on each trial. They were also told that after a few pairs of words and pictures, an instruction to recall the pictures would appear on the screen ("???"). They were instructed to recall as many pictures as possible, in any order. The task started (by pressing the space bar) with two practice blocks that contained two and three word-picture pairs. The first experimental block contained three word-picture pairs, and the number of pairs was increased by 1 in each subsequent block until the maximum of seven word-picture pairs was reached (in Block 5). Then this procedure started again until three cycles of five blocks (with 3, 4, 5, 6, and 7 items) were completed (15 blocks). Each word-picture pair was centered horizontally with the word presented below the picture (see Figure 1). Each word-picture pair was presented for 1500 ms. After each block, three question marks ("???") prompted participants to recall as many pictures from the previous block as possible, and the experimenter wrote down the responses on a sheet. Later, the responses were entered in an electronic form and coded for correctness. A correct response means that participants correctly named the object on the picture. An example of a six-item block is illustrated in Figure 1.

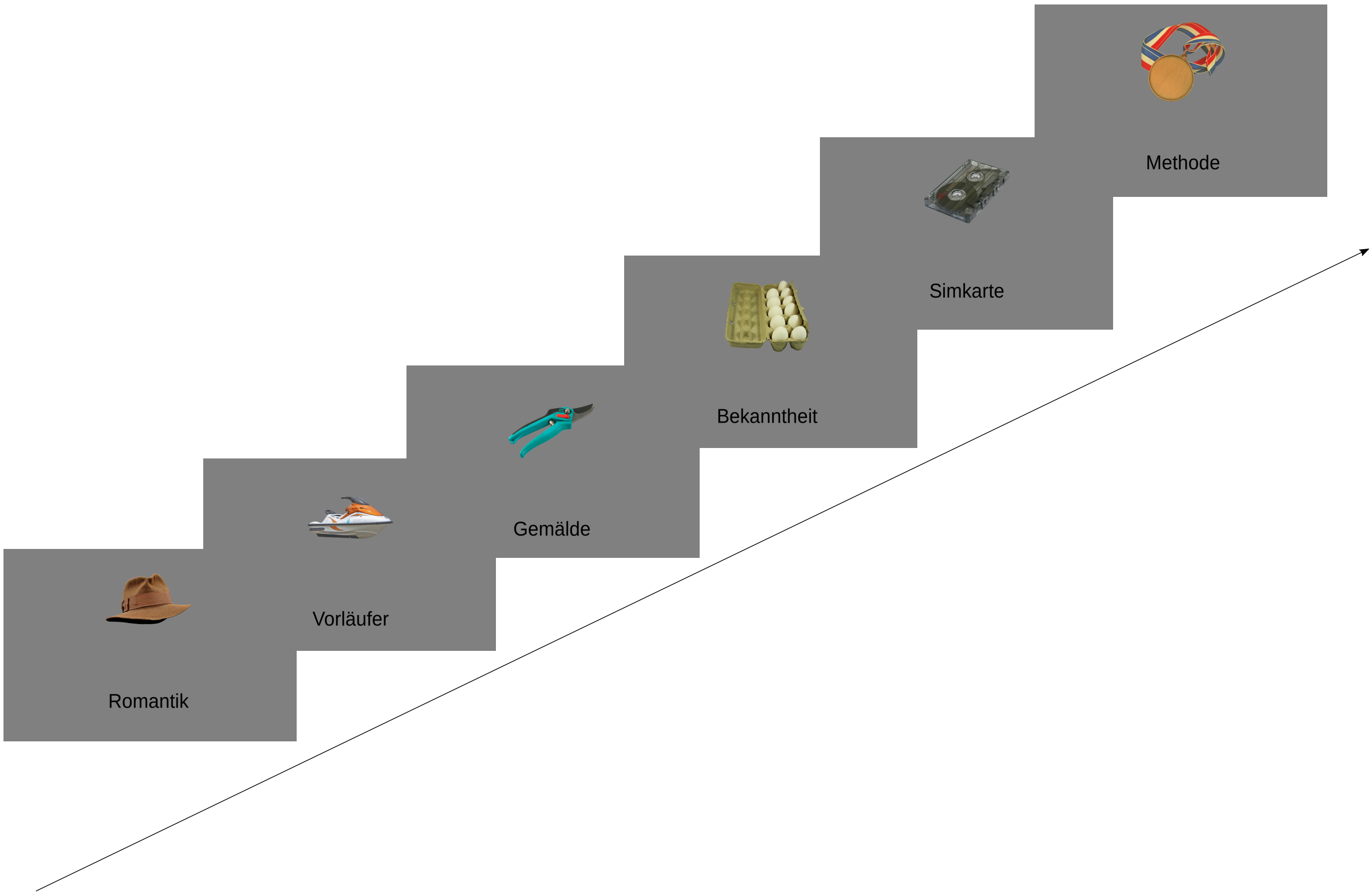

Figure 1. Example of a six-item block of the complex short-term memory task (with a smartphone-related word at position five). Words in English from left to right: romance, precursor, painting, renownedness, SIM card, method).

At the end of the first part (after block 15), the instructions for the prospective memory task were given. Participants were informed that they will have to perform the same task later during the testing session. They were instructed to inform the experimenter whenever they see a word of the category of musical instruments (saxophone was given as example) and were further informed that they will not be reminded to conduct this task. Moreover, they were informed that they were not required to recall a list that contained a prospective memory cue. Next, an unrelated distractor task (10 items from Raven matrices) was administered for a total retention interval of approximately 10 minutes. Each matrix, along with 8 possible solutions to complete a meaningful pattern, were presented on the screen and participants had 90 sec to enter their response before the next trial started. Then, the second part of the complex short-term memory task was administered following the same procedure as the first part (3 cycles of 5 blocks with increasing number of word-picture pairs; blocks 16-30). Prospective memory performance was scored as a *hit* when a participant recognized the prospective memory cue (the word trumpet) that always appeared at the 6th position of the last seven-item block (Block 30), and as a *miss* when the participant did not mention the prospective memory cue until the end of the recall phase of Block 30 (i.e., when the participant stated that they did not remember any further picture). At the end of the experiment, participants were asked whether they remembered that they were instructed to perform an additional task under specific conditions and what they had to do (control questions, see material).

Next, participants performed the delay discounting task (Koffarnus and Bickel 2014). They were instructed to choose between two hypothetical amounts of money, for example receiving 85 CHF (swiss francs) *now* or 100 CHF *in one year*. They were informed that they will not receive any money at the end of the game, but that they should behave as if this were the case (Johnson & Bickel, 2002). As in the example above, one option was always an immediate reward and the other a delayed reward. Both choices appeared simultaneously on the screen, one on the left side, and the other on the right side (with a white font size, Arial 60 pixels, on a black background). Participants were instructed to press the “v” (left) or “b” (right) button to indicate their choice. The choice options were preceded by a fixation cross (500 ms) and stayed on screen until participants responded. After response, a blank screen of 1500 ms was presented. The task consisted of three blocks that were presented in a random order. In one block, the amount for the immediate option was 5 CHF, and the one for the delayed option 10 CHF. In another block, the amount for the immediate option was 500 CHF, and the one for the delayed option 1000 CHF. In the remaining block, the amount for the immediate option was 500000 CHF, and the one for the delayed option 1000000 CHF. Each block consisted of five trials. The timepoint of the delayed reward was chosen by an adaptive procedure and varied between hours (1, 2, 3, 4, 6, 9, 12), days (1, 1.5, 2, 3, 4), weeks (1, 1.5, 2, 3), months (1, 2, 4, 6, 8) and years (1, 2, 3, 4, 5, 8, 12, 18, 25). The task lasted about three minutes.

After the delay discounting task, participants were asked whether they had an idea about the hypothesis of this study and to write it down in an empty text field in Limesurvey. None of the participants guessed the hypothesis of the study. In the last part of the experiment, participants filled out the questionnaires in the following order: Ward et al.'s scale, SAS, short scale of impulsiveness, and some final questions about smartphone usage, health, and life satisfaction. Since the last two groups of questions were not relevant for the current study, they are not described or analyzed further.

2.5 Data Analysis

2.5.1 Complex Short-Term Memory Task

In order to measure the effects of smartphone presence and possible interactions with task difficulty and smartphone-relatedness of the items, we computed the percent of remembered items per block size and item relatedness (related vs. unrelated) for each participant. For statistical analysis, we used a linear mixed effect (LME) model approach using the lmer4 package in R (Bates, Maechler, Bolker, & Walker, 2015). We used the fixed effects smartphone presence (present vs. absent), block size (3,4,5,6,7), and item relatedness (smartphone-related vs. smartphone-unrelated), and all interactions between these three variables. Given that an additional prospective memory task can result in increased cognitive costs with regards to the performance of the ongoing task (Meier et al., 2011; Rothen & Meier, 2014), we also included the fixed effect of experimental phase with the two levels baseline (block 1-14) and prospective memory task (block 15-29) in the model. In order to account for the repeated measurement, a random intercept was introduced for participants, and also a random slope for block size by participants (a random slope for item relatedness by participants was not included in the analyses since this random effect was estimated as zero). Block size (3-7) was treated as continuous predictor.

We reported the estimated effects, *SE*s, and 95% confidence intervals of all parameters, as well as the ANOVA statistics (*F*-tests using Satterthwaite's correction) using lmerTest in R (Kuznetsova, Brockhoff, & Christensen, 2017). We used sum coding (smartphone present = -1, smartphone absent =1; related items = -1, unrelated items = 1), thus the estimates reflect the deviation from the grand mean (intercept).

We would like to note that during preregistration, we indicated that our data would be analyzed by an analysis of variance (ANOVA). However, we ultimately decided to use the nearly equivalent linear mixed effect model approach because it allows to treat block size as a continuous as opposed to categorical predictor, which makes more sense given that the levels reflect continuous increments from 3-7. In addition, we used the linear mixed effect model because this model can encompass the additional interaction terms that are required for the moderator analysis by individual differences variables.

Given that the prospective memory cue always appeared in the last block (block 30) and participants were instructed to stop recall when they recognized the prospective cue, items from the last block were not included in the analysis. To allow for a fair comparison between the two experimental phases (baseline vs. additional prospective memory task), we also excluded the last block of the first half of the experiment (block 15) from analysis.

2.5.2 Prospective Memory Task

In order to test whether smartphone presence had an influence on the performance in the prospective memory task, we computed a logistic regression analysis with the predictor smartphone presence (present = -1, absent = 1) on success in noticing the prospective memory cue (1 = hit, 0 = missed).

3. Results

3.1 Description of the Sample and Correlations between Measurements

Means of demographic variables, smartphone dependency scores, and impulsiveness scores for the total sample and for participants in the smartphone present and absent conditions are reported in Table 1. There were no significant differences between participants of the smartphone present and absent condition regarding age, gender, education and smartphone dependency. There were also no significant differences between the smartphone present and absent group for the impulsiveness variables, except for sensation seeking. A table of correlations between the different measurements is reported in Table 2.

Table 1

Summary statistics for the total sample and for the smartphone present and absent condition

	Total	SP Present	SP Absent	*p*-value	ES
N	302	151	151		
Age [*M* (*SD*)]	22.4	22.2 (3.1)	22.6 (4.0)	.276	.13
Female (*N, %*)	205, 67.8%	97, 64.2%	108, 71.5%	.175	.08
Education [*M* (*SD*)]	3.0 (0.6)	2.9 (0.6)	3.0 (0.6)	.332	.11
Smartphone Dependency [*M* (*SD*)]					
Ward et al.'s scale	17.1 (6.1)	17.2 (6.1)	17.1 (6.2)	.881	-.02
SAS	23.73 (7.0)	24.0 (6.8)	23.5 (7.1)	.517	-.09
Impulsiveness [*M* (*SD*)]					
Urgency	2.57 (0.89)	2.50 (0.85)	2.64 (0.93)	.155	.16
Premeditation	2.59 (0.88)	2.54 (0.89)	2.64 (0.88)	.345	.11
Perseverance	2.45 (0.88)	2.52 (0.93)	2.37 (0.83)	.126	-.18
Sensation Seeking	3.41 (0.89)	3.52 (0.86)	3.30 (0.91)	.032	-.25
Delay discounting rate	0.18 (0.81)	0.15 (0.75)	0.18 (0.83)	.573	.07

Note. SP = smartphone, SAS = Smartphone Addiction Scale; *p*-values for age, education, smartphone dependency and impulsiveness are based on independent-sample *t*-tests (SP present vs. SP absent), and on χ^2 for the gender distribution. ES = effect size (Cohen's d for age, education, smartphone dependency and impulsiveness; phi for gender). The delay discounting rate was analyzed only for a sub-sample of *n* = 228 (see section 3.2.4 for more details).

Table 2

Correlations between the different measurements

	Gender	Age	CSTM	SD	SAS	Imp_urg	Imp_prem	Imp_pers	Imp_ss
Gender	-								
Age	.145*	-							
CSTM	-.006	.027	-						
SD	-.009	-.122*	-.079	-					
SAS	-.085	-.274***	-.040	.575***	-				
Imp_urg	.061	-.068	-.036	.109	.183**	-			
Imp_prem	-.103	-.075	-0.004	-.028	.034	.303***	-		
Imp_pers	.035	-.184**	0.087	.041	.286***	.193**	.273***	-	
Imp_ss	.217***	-.057	-0.035	-.116*	-.021	.269***	.255***	.021	-

Note. Age is coded as 1 = male and 0 = female. CSTM = sum of recalled items from the complex short-term memory task, SD = smartphone dependency (according to Ward et al., 2017's scale), SAS = smartphone addiction scale (Haug et al., 2015). The four impulsiveness variables (Imp) are those from the brief impulsive behavior scale (Kovaleva et al., 2012): urg = urgency, prem = premeditation, pers = perseverance, ss = sensation seeking. Note that the performance of the prospective memory task and the delayed discounting task are not included in this table because only a sub-sample was used for the analysis of these two measurements (see section 3.3.1 and 3.2.4 for more details). * $p < .05$, ** $p < .01$, *** $p < .001$.

3.2 Complex Short-Term Memory Task

3.2.1 General Performance

A Shapiro-Wilk normality test indicated normal distribution of the data ($p = .892$; see Figure 2). On average, participants recalled 82.6 items (*SD* = 14.2) out of the total of 136 items (150 minus 7 items from block 15 and 7 items from block 30). The number of remembered items ranged between 44 and 122. None of these extreme values was outside 3 *SD* of the overall mean, thus no participant was excluded from the analysis. In order to estimate the reliability of the complex short-term memory task, we compared the performance of the first and second half of the experiment as the two halves were counterbalanced for the critical conditions block size and item relatedness. The correlation between the scores of the first and second half of the task was $r = .717$ ($p < .001$), and Guttmans split-half-coefficient was .834, indicating good reliability (Nunnally & Bernstein, 1994).

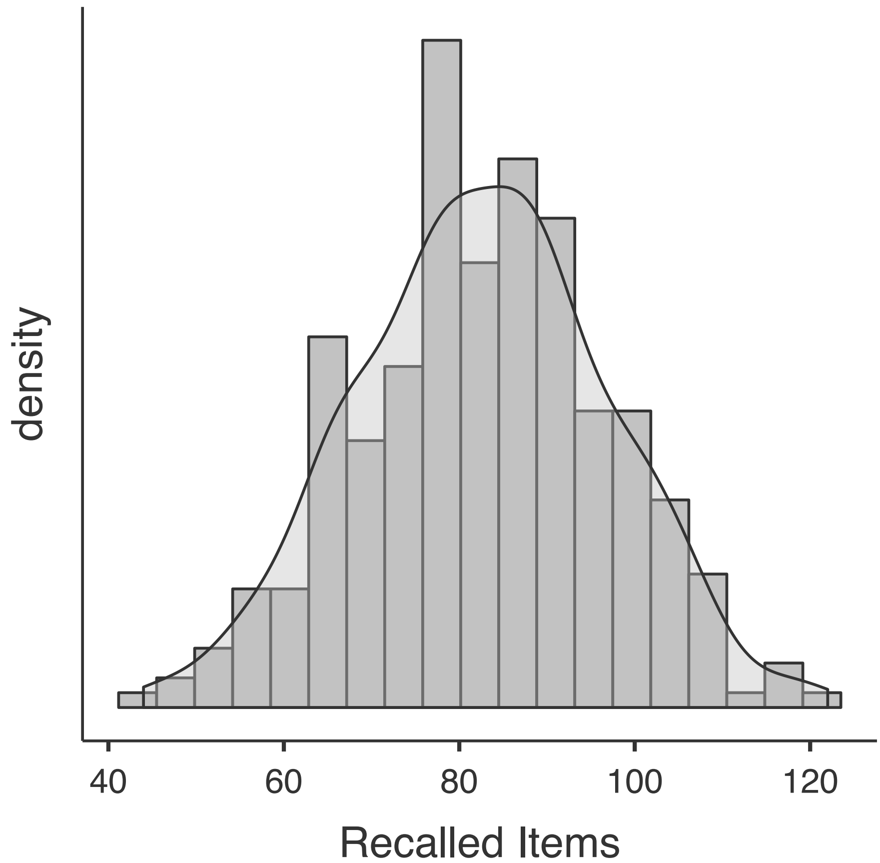

Figure 2. Distribution of the sum of recalled items from the complex short-term memory task.

3.2.2 Effect of Smartphone Presence

The results from the linear mixed effects model with the fixed effects smartphone presence (present vs. absent), block size (3,4,5,6,7), and item relatedness (smartphone-related vs. smartphone-unrelated), all interactions between these three variables, and the additional fixed effect of experimental phase (baseline, prospective memory task) are summarized in

Table 3. Most importantly, the analysis revealed no overall effect of smartphone presence, $F(1, 300) = 0.17$, $p = .676$. Performance was similar when the smartphone was present (M = 62.7%, SEM = 0.9) compared to when the smartphone was absent (M = 62.2%, SEM = 0.9). Contrary to our expectations, there was also no interaction between smartphone presence and block size, $F(1, 1206) = 0.57$, $p = .451$ (see Figure 3a), no interaction between smartphone presence and item relatedness, $F(1, 4525) = 0.09$, $p = .761$, and no three-way interaction between smartphone presence, block size, and item relatedness, $F(1, 4525) = 0.519$, $p = .471$.

As expected, performance decreased with increasing block size, $F(1, 1206) = 2183.45$, $p < .001$, and performance was slightly higher in the experimental phase without the prospective memory task, $F(1, 4525) = 8.70$, $p = .003$ (baseline: M = 63.1%, SEM = 0.6; prospective memory task: M = 61.8%, SEM = 0.6). Moreover, there was an interaction between item relatedness and block size, F(1, 4525 = 24.53, $p < .001$, suggesting an advantage of smartphone-related items for the larger block sizes (see Figure 3b).

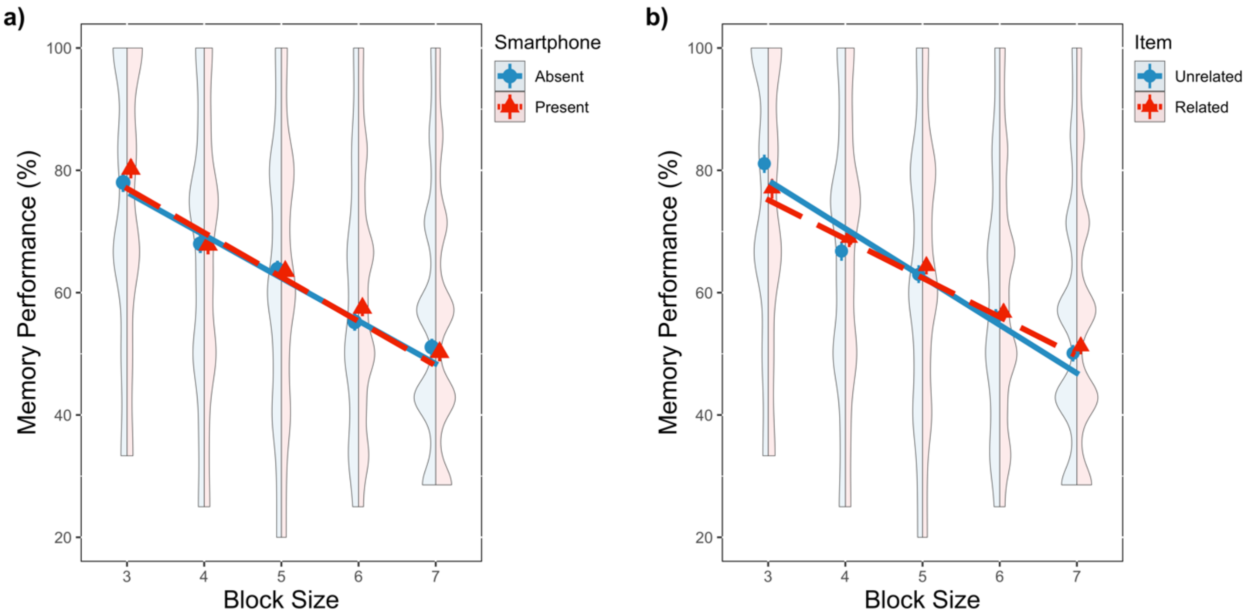

Figure 3. Performance in the complex short-term memory task (%) as a function of block size and (a) smartphone presence or (b) item relatedness. Dots represent the means

(with 95% confidence intervals), and lines represent the linear fits. The distribution of the underlying data is shown by the violin plots (rotated and split kernel density plots).

Table 3

Results of the linear mixed effects model analysis (including ANOVA statistics).

Coefficients	Estimate	*SE*	95% CI [LL, UL]	*F*	*p*
Intercept	62.48		-	-	-
Smartphone Presence (SP)	-0.25	0.61	[-1.44, 0.93]	0.17	.676
Block Size (BS)	-7.13	0.15	[-7.43, -6.83]	2183.45	<.001
Item Relatedness (IR)	-0.09	0.21	[-0.51, 0.34]	0.16	.692
Experimental Phase (EP)	0.63	0.21	[0.21, 1.05]	8.70	.003
SP x BS	0.11	0.15	[-0.18, 0.41]	0.57	.451
SP x IR	-0.07	0.21	[-0.49, 0.36]	0.09	.761
BS x IR	-0.75	0.15	[-1.05, -0.45]	24.53	<.001
SP x BS x IR	0.11	0.15	[-0.19, 0.41]	0.52	.471

Note. LL = lower limit, UL = upper limit, *SE* = standard error. Sum coding was used. The estimate of the intercept represents the grand mean. The estimate of smartphone presence represents the difference between the grand mean and the *smartphone absent* condition. The estimate of block size represents the difference in recalled items (in percent) for each increase in block size. The estimate of item relatedness represents the difference between the grand mean and the smartphone-unrelated item condition. ANOVA statistics was computed following Satterthwaite's method.

In the analysis above, the effect of item relatedness was assessed by comparing performance of the entire block with or without a smartphone-related item. However, it could be the case that the effect of smartphone-related items is limited to the performance for the specific image that was coupled with the smartphone-related word. In order to further explore the hypothesis that smartphone-related items enhance the cost of smartphone presence, we ran an additional analysis including only the performance for the images that were coupled with smartphone-related items (*n* = 14 per participant) and their word-length and frequency-matched smartphone-unrelated control items (also *n* = 14 per participant) with the fixed effects smartphone presence, item relatedness, and block size (and all interactions). This additional analysis showed that there was an advantage for remembering images that were associated with smartphone-related words (*M* = 69.4%, *SEM* = 0.9) when compared to the smartphone-unrelated control words (*M* = 63.2%, *SEM* = 0.9), $F(1, 2712) = 38.53$, $p < .001$, 95% CI [-4.10, -2.13]. This main effect suggests that there was increased attention when processing smartphone-related words, regardless of whether the smartphone was present or absent. Most importantly, this additional analysis further confirmed that there was no overall effect of smartphone presence, $F(1, 300) = 0.01$, $p = .923$, 95% CI [-1.39, 1.53], no interaction between smartphone presence and item relatedness, $F(1, 2712) = 0.48$, $p = .489$, 95% CI [-0.64, 1.33], no interaction between smartphone presence and block size, *F*(1, 2712 = 0.05, $p = .829$, 95% CI [-0.77, 0.62], and no three-way interaction, $F(1, 2712) = 0.65$, $p = .419$, 95% CI [-0.41, 0.98].

These results clearly show that there were no costs of smartphone presence on short-term memory, neither in the form of an overall effect, nor in the form of an interaction with block size or item relatedness. Therefore, these results do not support our initial hypothesis.

3.2.3 Smartphone Dependency as Moderator?

A summary of the mean values for the two measurements of smartphone dependency (Ward et al.'s scale and SAS) can be found in Table 1. The two measurements were correlated, $r_{Pearson} = .575$, *p* < 001 (see Table 2), and both showed high internal consistency (Cronbach's α for Ward et al.'s scale: 0.822; Cronbach's α for SAS: 0.807).

In order to test whether smartphone dependency moderated the effect of smartphone presence on memory performance, we extended the model reported above by smartphone dependency. More precisely, we added smartphone dependency as a continuous fixed effect predictor (mean centered), and the interaction between smartphone dependency and smartphone presence as the critical moderating effect. Two separate models were computed, one for Ward et al.'s scale and one for the SAS.

There was no moderating effect of smartphone dependency, neither for Ward et al.'s scale, estimate = -0.10, *SE* = 0.10, 95% CI [-0.30, 0.09], $F(1,298) = 1.13$, $p = .289$, nor for the SAS, estimate = -0.11, *SE* = 0.09, 95% CI [-0.28, 0.06], $F(1,298) = 1.72$, $p = .191$, see Figure 4. All other effects were highly similar to the effects in the analysis reported above in terms of estimates and there were no changes in accepting or rejecting the null hypothesis, thus we do not reiterate them here.

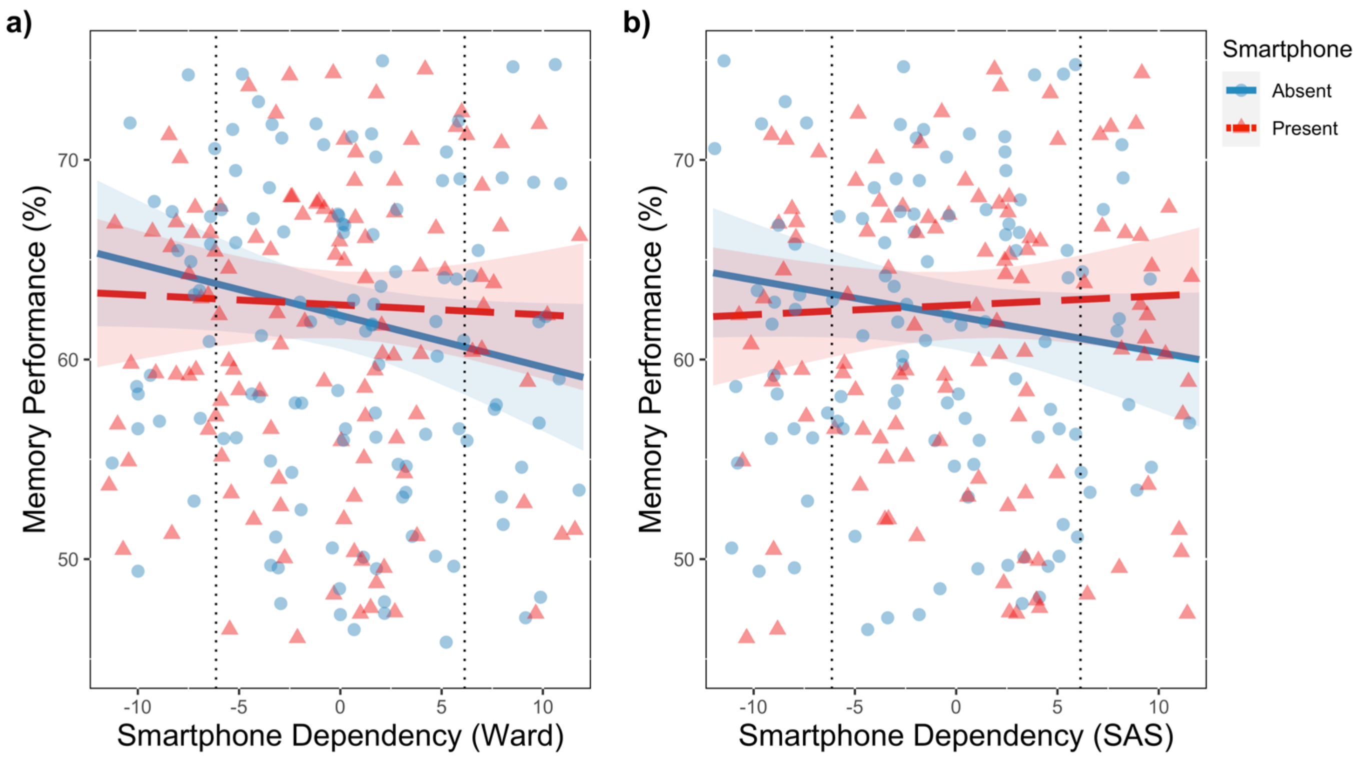

Figure 4. The figure depicts the non-significant interaction (moderating effect) between smartphone presence and smartphone dependency for the performance in the complex short-term memory task (a: Ward et al.'s scale, b: SAS). The lines represent the linear fits, and the area around the line represent 95% confidence intervals. The vertical dotted

line represents low (- 1 *SD*) and high (+ 1 *SD*) smartphone dependency. Each dot represents a participant. Datapoints are slightly jittered for better visibility.

3.2.4 Impulsiveness as Moderator?

A summary of mean impulsiveness values for the total sample, the smartphone present and absent condition, and the correlations between the different measurements of impulsiveness can be found in Table 1 and Table 2 (section 3.1). The measurements from the brief impulsive behavior scale showed acceptable internal consistency values (Cronbach's α for urgency: 0.692, Cronbach's α for premeditation: 0.833, Cronbach's α for perseverance: 0.650, and Cronbach's α for sensation seeking: 0.901.

In order to test whether impulsiveness moderated the effect of smartphone presence on memory performance, we computed the model for the complex short-term memory task reported above including the different variables of impulsiveness. A separate model was computed for each impulsiveness variable, including the mean-centered impulsiveness variable and the interaction between the impulsiveness variable and smartphone presence as the critical moderator term. We treated the impulsiveness variables (urgency, premeditation, perseverance, and sensation seeking) separately since a generalized factor of impulsiveness has not been found in previous studies (Keye, Wilhelm, & Oberauer, 2009), although the four factors were partly correlated in this study. In the delay-discounting rate analysis, fifty-nine participants (19.5%) were excluded from the analysis because their discounting rate was not consistent among the three measurements of delay discounting (10, 1000, 1000000; see Koffarnus & Bickel, 2014). In addition, data of the delay discounting task was missing from 15 participants. For the remaining sample (n = 228), the correlations between the three delay discounting rates (10, 1000, 1000000) were highly significant (all rs > .475, ps < .001). Consequently, only the mean (log) discounting rates from the three measurements was used for the analysis. Moreover, these mean discount rates were not correlated to the other measures of impulsiveness (all *p*s > .05): urgency $r = .086$, premeditation $r = .124$, perseverance $r = .078$, sensation seeking $r = .076$.

There was no moderating effect of any of the impulsiveness variables, as summarized in Table 4 (all *p*s > .245). Again, the estimates of the remaining parameters remained largely unchanged by the additional impulsiveness variables, so we do not reiterate them here.

Table 4

Results of the moderator analysis for the different variables of impulsiveness

Moderator term	estimate	*SE*	95% CI [LL, UL]	*F*	*p*
Urgency x SP	0.60	0.69	[-0.75, 1.95]	0.76	.383
Premeditation x SP	0.29	0.69	[-1.06, 1.65]	0.18	.670
Perseverance x SP	0.80	0.69	[-0.55, 2.16]	1.35	.247
Sensation Seeking x SP	0.23	0.69	[-1.12, 1.58]	0.11	.740
Delay discounting rate x SP	0.02	0.43	[-0.83, 0.87]	0.01	.968

Note. SP = smartphone presence, LL = lower limit, UL = upper limit, *SE* = standard error.

3.3 Prospective Memory

3.3.1 General Performance

The control questions regarding the prospective memory task revealed that nine participants (3.0%) either forgot the instruction for the prospective memory task completely or forgot the category (musical instruments) to which they were required to respond to. These participants were excluded from the analysis of prospective memory. From the remaining sample, 167 participants out of 293 (57.0%) completed the prospective memory task successfully.

3.3.2 Effect of Smartphone Presence

The logistic regression analysis with the predictor smartphone presence (smartphone present = -1, smartphone absent =1) on memory success (prospective memory cue detection: 1 = hit, 0 = missed) revealed that there was no effect of smartphone presence, estimate = 1.14, $SE = 0.12$, 95% CI [0.91,1.44], $z = 1.13$, $p = .259$. The predicted probability of detecting the prospective memory cue was 60.3% (*SE* = 16.9) for the smartphone absent condition, and 53.7% (*SE* = 16.5) for the smartphone present condition.

3.3.3 Smartphone Dependency as Moderator?

In order to test whether smartphone dependency moderated the effect of smartphone presence on prospective memory, we extended the logistic regression analysis by smartphone dependency. Again, we added smartphone dependency as continuous fixed effect predictor (mean centered), and the interaction between smartphone dependency and smartphone presence as the critical moderating effect. Two separate models were computed, one for Ward et al.'s scale and one for the SAS.

There was a significant moderating effect of smartphone dependency for Ward et al.'s scale, estimate = -0.04, *SE* = 0.02, 95% CI [0.92, 0.99], $z = -2.18$, $p = .030$, but not for the SAS, estimate < -0.01, *SE* = 0.02, 95% CI [0.96, 1.03], $z = -0.27$, $p = .785$. (see Figure 5 a, b). Simple slope tests for Ward et al.'s scale at low (-1 *SD*), mean (*M*), and high (+1 *SD*) smartphone dependency revealed a significant effect of smartphone presence for low smartphone dependency ($z = -2.37$, $p = .018$), but not for mean ($z = -1.26$, $p = .207$) or high ($z = 0.70$, $p = .485$) smartphone dependency. As shown in Figure 5 a, the probability of noticing the prospective cue was lower when the smartphone was present (vs. absent) for participants with low smartphone dependency. Interestingly, there was also a general decrease in the probability of noticing the prospective cue with increasing smartphone dependency regardless of smartphone presence, which was significant for Ward et al.'s scale, estimate = -0.06, *SE* = .02, 95% CI [0.91, 0.98], $z = -2.79$, $p = .005$. There was also a trend for the SAS, estimate = -0.03, *SE* = .02, 95% CI [0.96, 1.03], $z = -1.82$, $p = .069$ (see Figure 5 c, d).

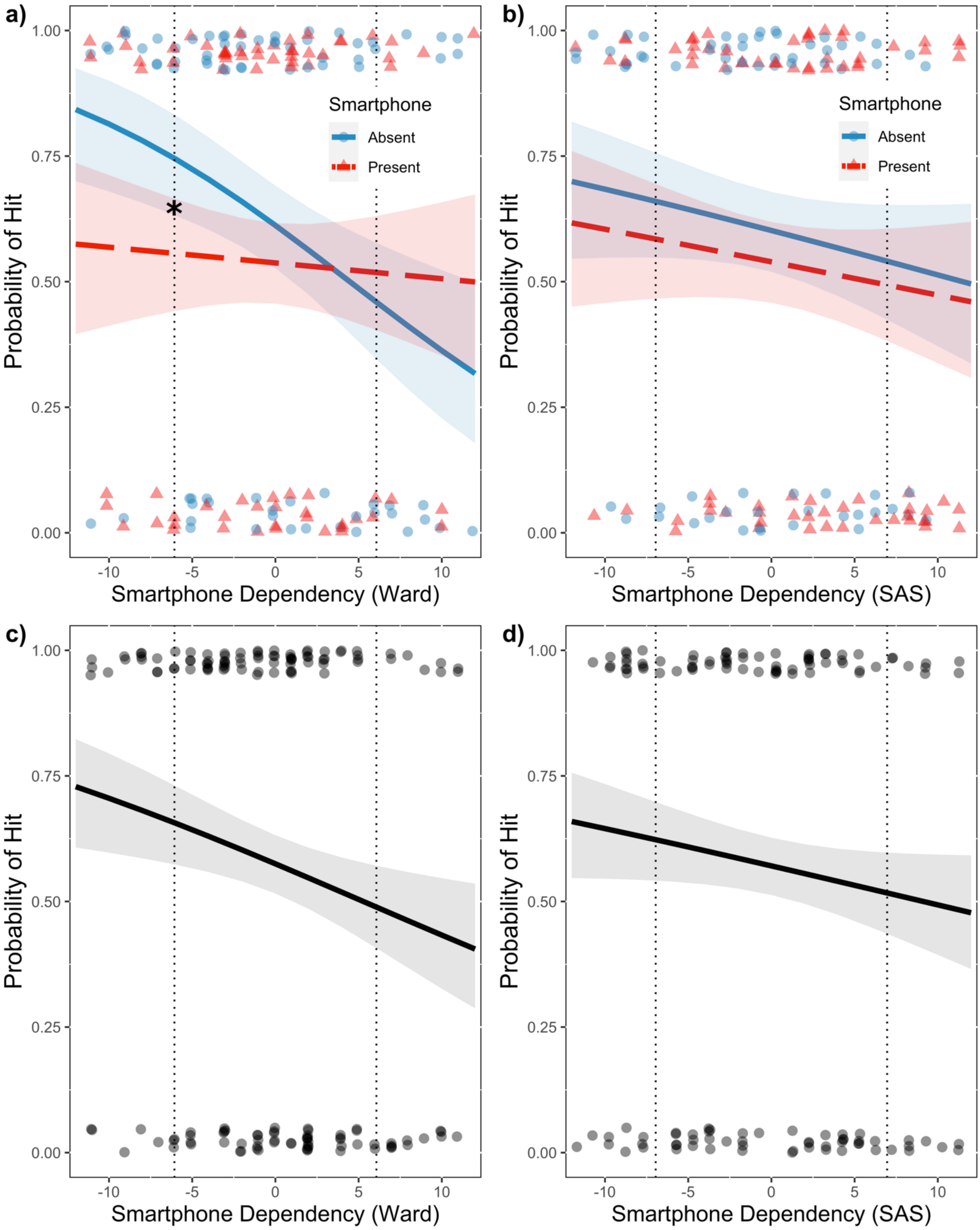

Figure 5. Probability of noticing the prospective memory cue. The top panel shows the moderating effect of smartphone dependency (a: Ward et al.'s scale, b: SAS). The bottom panel shows the overall effect of smartphone dependency (c: Ward et al.'s scale, d: SAS). Area around the lines represent 95% confidence intervals. The vertical dotted line represents

low (- 1 *SD*) and high (+ 1 *SD*) smartphone dependency. The asterisk in a) indicates a significant difference ($p < .05$) between the smartphone present and absent condition for participants with low smartphone dependency. Each dot represents a participant. Datapoints are slightly jittered on the y-axis for better visibility.

3.3.4 Impulsiveness as Moderator?

In order to test whether impulsiveness moderated the effect of smartphone presence on prospective memory, we computed the logistic regression model for the prospective memory task again with the different variables of impulsiveness and their interaction with smartphone presence separately for each impulsiveness variable. For the analysis of the moderating role of delay discounting, a sub-sample of $n = 228$ was included in the analysis (see section 3.2.4 for sample size information). There was no moderating effect of the impulsiveness variables, as summarized in Table 5 (all *p*s > .194).

Table 5

Statistical results of the moderating effects for the different variables of impulsiveness.

Moderator term	estimate	*SE*	95% CI [LL, UL]	*z*	*p*
Urgency x SP	1.01	0.13	[0.78, 1.31]	0.07	.948
Premeditation x SP	1.00	0.13	[0.77, 1.30]	-0.02	.982
Perseverance x SP	0.93	0.14	[0.71, 1.22]	-0.54	.590
Sensation Seeking x SP	1.10	0.14	[0.84, 1.44]	0.72	.471
Delay discounting rate x SP	0.89	0.09	[0.75, 1.06]	-1.30	.194

Note. SP = smartphone presence, LL = lower limit, UL = upper limit, *SE* = standard error. Estimates are the log odds ratio associated with a one-unit change of the predictor.

3.4 Is There an Effect of Smartphone Presence on the Delay Discounting Rate?

So far, the delay discounting rate was considered as a possible moderator of impulsiveness for the effect of smartphone presence on memory performance. However, the delay discounting rate can also be regarded as a dependent variable, since half of the sample performed this task in the smartphone present condition, and the other half in the smartphone absent condition. Previous research found that people show a more impulsive decision-making style under higher cognitive load, expressed, for instance, as an increased preference for the immediate reward in a delay discounting task (e.g., Hinson, Jameson, & Whitney, 2003). It is therefore possible that the cognitive resources occupied by smartphone presence influenced behavior in this task. This hypothesis was tested by an independent sample *t*-test with the variable smartphone presence (present vs. absent). There was no effect of smartphone presence on the delay discounting rate, $t(217) = 0.39$, $p = .699$, Cohen's $d = 0.05$.

3.5 Do our Data Support the Null Hypothesis?

In addition to the pre-registered frequentist analyses that we have reported so far, we computed Bayesian statistics in order to further assess the effect of smartphone presence. The relative plausibility of two hypotheses (H1 or H0) can be quantified by a Bayes Factor (BF). For example, a BF_{10} of 5 means that the data is 5 times more likely under H1 than under H0, whereas a BF_{10} of 1 means that both hypotheses are equally plausible. BFs_{10} between 1/3 and 3 are considered as inconclusive, and BFs_{10} below 1/3 are considered as evidence in favor of H0 (Jeffreys, 1939).

Complex short-term memory task performance was assessed by comparing the mean percentage of all remembered items (over all conditions) between the smartphone present and absent condition using a Bayesian independent sample *t*-test. For the prospective memory task, a Bayesian contingency table was computed. These tests were run in JASP (JASP Team, 2016) using default priors (H1: smartphone present ≠ smartphone absent).

The BF_{10} for the complex short-term memory task was 0.161, and the BF_{10} for the prospective memory task was 0.277, thus providing evidence against a difference between smartphone presence and absence (H1). In other words, the null hypothesis (H0) is 6.21 (1/0.161) times more likely than H1 for the complex short-term memory task, and 3.61 (1/0.277) times more likely than H1 for the prospective memory task.

3.6 Exploratory analysis

Following the suggestion of an anonymous reviewer, we also tested whether gender might be a moderator for the effect of smartphone presence. To this end, we added gender (male, female) as fixed effect predictor and the interaction between smartphone presence and gender as the critical moderating effect to the model for the complex short term memory task (see section 3.2.2), and also to the model of the prospective memory task (see section 3.3.2). There was no moderating effect of gender, neither for the complex short term memory task, estimate = 0.59, $SE = 0.65$, $F(1, 298) = 0.81$, $p = .368$, nor for the prospective memory task, estimate = 0.94, $SE = 0.13$, $z = -0.52$, $p = .604$.

4. Discussion

The aim of this study was to extend previous findings related to the detrimental effects of the mere presence of one's own smartphone on cognitive performance (Thornton et al., 2014; Ward et al., 2017). The rationale behind the study was that the presence of a highly relevant and salient object like one's smartphone attracts attention even when it is not in use, which in turn reduces the availability of cognitive resources for other tasks (Thornton et al., 2014; Ward et al., 2017). We did not find support for a negative effect of smartphone presence on short-term memory. The number of recalled items was comparable between the condition when the smartphone was present on the desk as compared to when it was absent. There was also no support for our hypotheses that the detrimental effect of smartphone presence would be more pronounced when task difficulty is high, when smartphone-related items were processed during encoding, or when the individual dependency on the smartphone was high.

The lack of an effect of smartphone presence on short-term memory performance was surprising since both Ward et al.'s (2017) and our task rely on similar basic features of cognitive functions. Both studies measured the ability to simultaneously maintain information in memory while processing additional unrelated information. Nevertheless, a possible reason for the absence of an effect of smartphone presence in this study can be found in task differences. In our task, the unrelated information was processed *during* the encoding of the to-be-remembered items, and the encoding process was relatively intense (pace of 1.5 s), so there was little time for rehearsal of the items before recall. In Ward et al.'s task (2017), the to-be-remembered item was always encoded *after* the processing of the unrelated information, and the encoding phase and the distractor task were not time-limited, potentially allowing for verbal rehearsal before recall was required. One could argue that verbal rehearsal or switching between the processing of related and unrelated information was the critical part of the task used by Ward et al. (2017) that was susceptible to the attentional resources occupied by the smartphone, and not so much the encoding and short-term storage of the items. However, attentional control for the switch between related and unrelated information and verbal rehearsal were, at least to some extent, also involved in our task. It is therefore unlikely that the differences in the tasks can entirely account for the absence of an effect of smartphone presence on memory performance in this study. Another methodological difference can be found in the manipulation of the smartphone absent condition. While participants in the absent condition in Ward et al. (2017) left the smartphone in a different room, participants in our study set the smartphone aside but not in a different room—although clearly outside of peripersonal space. Not putting the smartphone in a different room might have reduced the benefits of the smartphone absent condition in this study. However, Ward et al. (2017) also found better performance in a condition where the smartphone was left in a nearby pocket/bag compared to the condition with the smartphone on the desk (the difference was significant for the measurement of fluid intelligence, and also for participants with high smartphone dependency for working memory capacity). Based on these findings, it is unlikely that putting the smartphone out of reach and out of sight would not show a benefit when compared to the smartphone present condition in this study. On a related note, a possible elicitation of surprise and anxiety when the smartphone is placed away from the participants in the absent condition has been discussed in Ward et al. (2017). Accordingly, separation from one's smartphone can increase anxiety (e.g., Cheever et al 2014; Clayton et al. 2015; Schmidt et al 2018), which in turn can undermine executive functioning (Hartanto and Yang 2016). Thus, being separated from one's smartphone can also have negative effects that might counteract a potential benefit of smartphone absence as expected in this study. However, in most of these studies, participants were *unexpectedly* separated from their phones (Cheever et al. 2014), and the smartphone absence was made noticeable to the participant by, for instance, placing a person without their smartphone next to other persons who still have the device in their possession (Cheever, Rosen, Carrier, & Chavez, 2014), or by forcing them to hear their smartphone ring while being unable to answer (Clayton, Leshner, & Almond, 2015). In our study, it is very unlikely that participants were surprised by the removal of smartphones from their possession since this is a common practice in the context of psychological experiments, and participants were not confronted with unanswerable calls. Nevertheless, participants' expectations about experimental procedures and handling of personal belongings, as well as anxiety-induced impairments in cognitive performance due to smartphone separation (Hartanto & Yang, 2016), could be assessed more systematically in future research.

Another difference between our and Ward et al.'s study might be that the experimenter played a somewhat more active role in our study by noting down responses and occasionally guiding participants through the experimental procedure. This sociable and involved conduct of the experimenter might have impacted the overall results, however why the conduct of the experimenter would have interfered with an effect of smartphone presence (present vs. absent) remains unclear. Besides these methodological differences, it is also conceivable that there was a difference in the attitude towards one's own smartphone and/or the coping strategies for the distracting influence of smartphone presence between the two samples (US sample in Ward et al.'s study vs. Swiss sample in this study), but we do not have indications for the presence or source for such differences.

Forgetting to realize to do something due to distraction by smartphone presence could be an important negative side effect of smartphones that has not yet attracted much attention in research. Thus, a further aim of this study was to investigate the effect of smartphone presence on prospective memory. Our data support the null hypothesis that there is no overall effect of smartphone presence on prospective memory. Nevertheless, there was a moderating effect of smartphone dependency where the probability of detecting the prospective memory cue was higher when the smartphone was absent (vs. present) for low smartphone dependency (as measured by Ward et al.'s scale). While this conditional effect of smartphone presence is in line with our hypothesis, the pattern of interaction was unexpected. The moderating effect found in Ward et al. (2017) with the same scale showed that the cost of smartphone presence was more pronounced for people with higher levels of smartphone dependency, possibly because the smartphone is even more salient and its presence all the more distracting for them. Our results seem to suggest that the benefit of smartphone absence disappears for people with higher levels of smartphone dependency, as if the negative effects of missing one's own smartphone when it is absent (Hartanto & Yang, 2016) counteracts the positive effect of smartphone absence. In other words, both low smartphone dependency and absence of the smartphone on the desk are required for a performance benefit. Although this might be an interesting hypothesis for future research, we do not want to overinterpret this finding at this point in time since this moderating effect of smartphone dependency was only found with Ward et al.'s scale and not with the SAS. Another pattern more consistent across the two measurements (Ward et al.'s scale and SAS) was a negative relationship between smartphone dependency and the probability of detecting the prospective memory cue. This pattern suggests that certain individual traits or behaviors lead to both a tendency to become more dependent on one's own smartphone and also to miss prospective memory cues more often.

Possible candidates for such characteristics might be variables that were related to smartphone dependency in previous studies, such as extraversion, increased sleep disturbances, depression (Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015; Smetaniuk, 2014), higher stress levels, lower physical fitness (Haug et al., 2015), or lower level of education (Kwon, Lee, et al., 2013). Alternatively, one could also speculate that the negative relationship between smartphone dependency and the probability of detecting the prospective memory cue reflects that people with lower prospective memory abilities rely more on their smartphones to remember intended actions and are therefore more prone to smartphone addiction.

To conclude, we found no evidence that the mere presence of a smartphone on the desk drains our brains. However, it is important to highlight that we do not interpret our (null) results in favor of an absence of a distracting effect of smartphone presence in general. There is firm evidence that the mere presence of personally relevant stimuli can impair performance on cognitive tasks (Bargh, 1982; Geller & Shaver, 1976; Wingenfeld et al., 2006). Our results should therefore not motivate people to put their smartphones on their desks at work. It is plausible that smartphone presence in specific contexts creates distraction because smartphones increase the tendency to spontaneously attend to and use the smartphone during working time (End, Worthman, Mathews, & Wetterau, 2009; Oulasvirta, Rattenbury, Ma, & Raita, 2012) and also increase the risk of being distracted by message notifications (Stothart et al., 2015). Our results show that a distracting effect of the mere presence of a smartphone cannot be generalized to other conceptually similar tasks as easily as we initially presumed based on Ward et al.'s findings (2017). More research is needed to define the boundary conditions of a distracting effect of the mere presence of one's smartphone in their immediate vicinity. It is also advisable for future studies to involve an exact replication condition from Ward et al.'s (2017) working memory task in order to further assess the robustness and generalizability of their findings. Moreover, future studies could explore the practical relevance of potential cognitive costs of smartphone presence by using a longer task that involves a variety of complex cognitive operations, mimicking more closely a real working situation.

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