Pre-Registered Report

Hard to Resist?

The Effect of Smartphone Visibility and Notifications on Response Inhibition

Niklas Johannes, Harm Veling, Thijs Verwijmeren, and Moniek Buijzen

Behavioural Science Institute, Radboud University, Nijmegen, The Netherlands

Abstract: Because more and more young people are constantly presented with the opportunity to access information and connect to others via their smartphones, they report to be in a state of permanent alertness. In the current study, we define such a state as *smartphone vigilance*, an awareness that one can always get connected to others in combination with a permanent readiness to respond to incoming smartphone notifications. We hypothesized that constantly resisting the urge to interact with their phones draws on response inhibition, and hence interferes with students' ability to inhibit prepotent responses in a concurrent task. To test this, we conducted a preregistered experiment, employing a Bayesian sequential sampling design, where we manipulated smartphone visibility and smartphone notifications during a stop-signal task that measures the ability to inhibit prepotent responses. The task was constructed such that we could disentangle response inhibition from action selection. Results show that the mere visibility of a smartphone is sufficient to experience vigilance and distraction, and that this is enhanced when students receive notifications. Curiously enough, these strong experiences were unrelated to stop-signal task performance. These findings raise new questions about when and how smartphones can impact performance.

Keywords: smartphones, visibility, notifications, vigilance, inhibition, self-regulation

Every year, the publisher *Langenscheidt* elects the youth word of the year in Germany, which is supposed to best reflect generational trends and issues important to youth. For 2015, they chose *smombie*, a portmanteau of smartphone and zombie (Süddeutsche Zeitung, 2015). According to the publisher, the term represents a phenomenon that recent research has termed being "permanently online" (Vorderer & Kohring, 2013). More and more young users report being in a state of permanent readiness to respond to their smartphones (Pew Research Center, 2015). Such a state of mind can be understood as vigilance (Bayer, Campbell, & Ling, 2015), because young users are constantly confronted with the desire to check their phones to satisfy social, informational, and hedonic needs (Chun, Lee, & Kim, 2012; Karapanos, Teixeira, & Gouveia, 2016). Resisting those urges requires one of the most basic forms of executive functions (EF), namely, behavioral inhibition (Friedman et al., 2008; Jurado & Rosselli, 2007). Therefore, with the current study we aimed to test whether smartphone vigilance indeed draws on inhibitory capacities, thereby decreasing performance in a simultaneous inhibition task.

Smartphones and Inhibition Failure

Students in particular frequently fail to resist checking their smartphones, because smartphone checking has shown to be the most frequent interruption during self-study (Calderwood, Ackerman, & Conklin, 2014), characterized by nonpurposeful, reward-based checks (Oulasvirta, Rattenbury, Ma, & Raita, 2012). Giving in to those checks has been associated negatively with various performance outcomes, such as grades (for reviews, see Chein, Wilmer, & Sherman, 2017; Chen & Yan, 2016; van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015).

Despite displaying a willingness to refrain from checking their phones in the face of more important tasks, students' repeated failures to do so demonstrates that inhibiting phone checking can be difficult. Inhibiting to give in to smartphone distractions can be considered an EF process that lies at the heart of self-regulation (Hofmann, Schmeichel, & Baddeley, 2012; Inzlicht & Berkman, 2015). EFs involve "a set of general-purpose control mechanisms, often linked to the pre-frontal cortex of the brain, that regulate the dynamics of human cognition and action" (Miyake & Friedman, 2012, p. 8). EF failure is related to various undesirable outcomes, such as overeating (Cserjési, Luminet, Poncelet, & Lénárd, 2009) and academic problems (Best, Miller, & Naglieri, 2011). Different authors have suggested different classifications for EFs, but there seems to be consensus on three components (e.g., Diamond, 2014): attentional control or working memory capacity; shifting, which refers to switching between tasks or mental sets; and inhibition, which refers to the suppression of task-irrelevant thoughts, actions, dominant responses, or urges.

https://doi.org/10.1027/1864-1105/a000248

Resisting thoughts about desirable outcomes provided by smartphones and resisting the urge to check one's phone lie at the intersection of two forms of inhibition: inhibitory control of attention and the inhibition of learned motor responses. The former describes deliberately suppressing attention to stimuli (Diamond, 2014), for instance, smartphone notifications, that are irrelevant to the task at hand. The latter refers to inhibiting the learned response to pick one's phone up either to check whether new notifications have come in or to respond to a notification (Soror, Hammer, Steelman, Davis, & Limayem, 2015).

There are a number of empirical reasons to suspect that inhibition (failure) is indeed related to smartphone use. First, individuals with problematic smartphone (Roberts & Pirog, 2013; Smetaniuk, 2014) and instant messaging use (Levine, Waite, & Bowman, 2013) also display high impulsivity, as do those who engage in more multitasking (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013). Second, Hadlington (2015) found a strong relationship between problematic mobile phone use and everyday cognitive failures. Finally, Sanbonmatsu et al. (2013) found that those with low executive control were more likely to report higher levels of media multitasking, including smartphone use.

Smartphone Vigilance

With more and more users reporting to be in a state of alertness to respond to their devices (Pew Research Center, 2015) or even entrapment (Hall & Baym, 2012), we can understand this permanent alertness as a state of vigilance. Vigilance is traditionally defined in the context of monitoring work objectives as "the ability of organisms to maintain their focus of attention and to remain alert to stimuli over prolonged periods of time" (Warm, Parasuraman, & Matthews, 2008, p. 433). Smartphone vigilance can be understood similarly, but not as the primary object of focused attention, but rather as ongoing alertness parallel to other tasks. Seo, Kim, and David (2015) refer to the state as connectedness, "the inclination or investment to remain connected with others or being available to others through phone and other mobile technologies" (p. 671). In the present study we define smartphone vigilance as a state of being aware that one can always get connected with others or access information, accompanied by a permanent readiness to respond to incoming smartphone stimuli (Bayer et al., 2015).

Smartphone vigilance may thus continuously interfere with the inhibition process. Students need to inhibit both their behaviorally learned response to check for notifications as well as thoughts about the potential rewards their phones offer. By taxing the EF of inhibition, smartphone vigilance may thus impair performance on a simultaneous task requiring inhibition.

Although such a position has not been explicitly tested, other research suggests that smartphone vigilance indeed taxes EFs. For instance, Shelton, Elliott, Eaves, and Exner (2009) showed that hearing a phone ring during a lexical decision task resulted in performance decrements; moreover, participants displayed increased recovery times from phone rings compared with other tones. In an innovative experiment, Stothart, Mitchum, and Yehnert (2015) demonstrated that students could be distracted by texts or calls without even responding to those notifications. During a sustained attention to response task (SART), participants received notifications on their own phones sent by the experimenters (not knowing they would be texted or called). During a SART, participants are asked to press a key every time a target number appears (1–9), unless a non-target number is displayed (e.g., 3). Owing to its repetitive nature, the SART requires a prolonged period of attention. Receiving notifications resulted in diminished performance in the SART. Further, the authors concluded that the magnitude of the effect was comparable to using the phone while driving. Thornton, Faires, Robbins, and Rollins (2014) employed a similar design, but showed that receiving a notification might not be necessary. In two studies, students performed attention tasks with a phone on the table that did not receive any notifications. Merely presence of the experimenter's or participants' phones led to diminished performance.

However, none of these studies explicitly manipulated or measured vigilance, a psychological state. Rather, they manipulated smartphone visibility and notifications, which we believe result in vigilance, because they best mimic real-life situations that induce vigilance. In addition, because both Stothart et al. (2015) and Thornton et al. (2014) measured attention, the effect of smartphone vigilance on inhibition remains to be examined. Consequently, we planned to extend previous research using similar manipulations (visibility and notifications) that should induce smartphone vigilance. Besides measuring self-reported vigilance, we tested whether these manipulations influence performance on a validated and established task tapping inhibition, a modified stop-signal task (Logan, 1994; Verbruggen & Logan, 2008).

Stop-Signal Task

In a stop-signal task (SST), participants react to a stimulus during go-trials by, for instance, indicating the direction of arrows, unless they hear or see a stop signal (i.e., stop-signal trials). Timing of the stop signal is adjusted dynamically depending on participants' performance using a staircase procedure: The stop signal is presented earlier when participants fail to stop and later when participants succeed in stopping. This procedure allows for estimating the time to stop a response (the so-called stop-signal reaction time, SSRT), which is considered a measure of response inhibition. We expected smartphone visibility and notifications to induce vigilance and thus impair response inhibition, thereby increasing SSRT.

Importantly, recent work suggests that stop-signal trials not only require response inhibition; participants also have to update their current action plan (i.e., update the automated go-response to the alternative response, stopping) as well as update their attention (i.e., detecting the stop-signal; Verbruggen, Aron, Stevens, & Chambers, 2010; Verbruggen, Stevens, & Chambers, 2014). For the sake of brevity, we refer to these processes as *action selection*. Therefore, to be able to distinguish between response inhibition and action selection, we also employed trials that require a double-response (double-response task, DRT). During double-response trials, participants carry out not only the automated response, but also a second one (e.g., pressing the spacebar after categorizing the direction of an arrow). The task thus permitted us to explore the possibility that smartphone visibility and notifications have an effect on action selection (i.e., double-response reaction times, DRT2). We hypothesized that compared with a no-visibility-no-notifications control condition, the visibility-without-notifications condition would have a negative effect on response inhibition (H_{1a}), and the visibility-with-notifications condition would have a negative effect on response inhibition as well (H_{1b}). In addition, we explored whether visibility without notifications differed from visibility with notifications.

Method

We conducted an experiment in order to examine the influence of smartphone visibility and notifications on the EF of inhibition by employing a modified stop-signal task, that is, a context-cueing task. Readers can find study materials and data on the Open Science Framework (https://osf.io/k3p54/). We obtained approval from the institute's IRB (approval code: ECSW2016-0905-392a).

Participants and Sampling Design

Even though previous research on smartphone vigilance found medium-sized effects (Stothart et al., 2015; Thornton et al., 2014), these effects were demonstrated mainly for attention, not inhibition. Consequently, we could not be certain those effect sizes would apply to our experiment. Without certainty about an expected effect size, a power analysis for a frequentist analysis would likely yield an inaccurate sample size estimation. In addition, preregistered reports should allow us to quantify support in the data for possible null-findings, which is not possible under a frequentist framework (Wagenmakers, 2007). Therefore, we employed a sequential Bayesian sampling design (Schönbrodt, Wagenmakers, Zehetleitner, & Perugini, 2017). Such a design allowed us to address both issues of power and support for null effects: First, sequential Bayesian designs are flexible and resource-efficient, because they allowed us to continuously monitor the data, thus circumventing the risk of incorrectly calculating power. Second, Bayesian analyses can quantify support for the lack of an effect (Schönbrodt et al., 2017).

Bayesian analyses let researchers assign a probability distribution of effect sizes that they assume is plausible for their study. This so-called prior distribution is then compared with the likelihood distribution for the observed data to form the posterior distribution. Thus, the posterior distribution represents the distribution of effect sizes for the observed data taking into account the researcher's prior belief about the effect. Comparing the posterior with the prior tells us how much the information from the data has updated our prior belief. In addition to estimating the posterior distribution of effect sizes (i.e., parameter estimation), Bayesian analyses can also be used to select and compare competing hypotheses by using the so-called Bayes Factor (BF). Comparing the prior with the posterior at an effect size of zero, the BF indicates how much more the data are likely under the alternative hypothesis than under the null hypothesis (or vice versa). For instance, $BF_{10} = 6$ means the data are six times more likely under the alternative hypothesis than under the null hypothesis, and $BF_{01} = 6$ means the data are six times more likely under the null hypothesis than under the alternative hypothesis (for an introduction, see Wagenmakers et al., 2018).

We set a minimum sample size of $n = 20$ per condition and a maximum sample size of $n = 50$ (after implementing exclusions). As a stopping rule, we set an a priori threshold of 6 for the BF for BF_{10} and 6 for BF_{01} as recommended by Schönbrodt et al. (2017) for all direct comparisons. Because we did not reach the boundary conditions for H_{1a} or H_{1b} after the minimum sample size, we continued sampling until the maximum sample size. Overall, 178 people participated in our study, of whom we retained 154 valid cases after applying exclusion criteria (see next section). Participants (113 female, 73%, $M_{age} = 21.70$, $SD_{age} = 2.58$) were students from a university in The Netherlands, who received €5 or course credit. They owned a smartphone for multiple years ($M = 6.74$, $SD = 2.04$), and most of them estimated checking their phones rather frequently per day, with 84% indicating to check their phones 20 times or more.

Procedure

Manipulation

We employed a between-subjects design with three groups (no-visibility-no-notifications vs. visibility-without-notifications vs. visibility-with-notifications). Before signing up for the study, participants were informed that the experiment would be about cognitive performance and smartphones, and that they should be willing to have an experimenter change their phone settings to silent or vibrate mode.

Upon arrival, the experimenter welcomed participants and randomly assigned them to one of the conditions, followed by the context-cueing task. The experimenter told participants that they would set their phones to either silent or vibrate mode. By setting participants' phones either to flight mode (visibility-without-notifications condition, the alleged silent condition) or disconnecting it from the Internet, with vibrate mode on (visibility-with-notifications condition, the alleged vibrate condition), we planned to induce vigilance. In the no-visibility-no-notifications control condition, a notebook was placed on the table.

In the visibility condition, participants' phones were set to flight mode with silent mode on to make sure no notifications would come in. Yet, participants did not know whether their phone was in silent or in vibrate mode; thus, because they believed a notification could come in at any time, they were likely to be vigilant. The manipulation thus aimed to reproduce the vigilant status of a majority of students in their everyday lives, but without the possibility of actually receiving a notification.

In the notifications condition, participants' phones were disconnected from the Internet, with vibrate mode on. This way, they could only receive regular SMS, whose frequency is negligible compared with instant messaging services such as WhatsApp (bitkom, 2015). The chance was thus minimized that they received a notification not sent by the experimenter (preventing exclusion; see next section). During the last 10 of 32 practice trials of each block, they received three text messages, making their phones vibrate, separated by 7 s so that participants would not mistake the notifications for a call. The SMS were sent by the program to the number they indicated when registering for the experiment. Because participants were not allowed to check their phones, they could not be sure whether one of their personal contacts had messaged them or the experimenter. The manipulation thus aimed to induce the status of alertness to check one's messages, that is, participants were likely to be vigilant.

In the no-visibility-no-notifications control condition, participants set their phones to silent mode and stored it in the pockets of their jackets or in their handbags, which they put in the corner of the cubicle. This way, participants could not feel their phones in their pockets, limiting the potentially confounding effect of sensory perception of their smartphone, which in itself could induce vigilance. We decided not to remove participants' phones from the room, because smartphone separation has shown to be detrimental to EF in its own right (Hartanto & Yang, 2016). In addition, a notebook of similar size to a smartphone was placed on the table to make sure differences between the groups did not arise simply because there was a graspable object on the table (Przybylski & Weinstein, 2013).

The notebook or participants' phones were put on the table next to their dominant hand, display-down, so participants were blind to the condition and could not see whether their displays lighted up. After the experiment, participants were fully debriefed and received their compensation.

Response Inhibition Measure

To measure response inhibition, we employed a version of the stop-signal task known as the context-cueing task (e.g., Verbruggen et al., 2010). This task allows for a distinction between possible effects of the manipulations on response inhibition versus action selection. During this task, participants were instructed to categorize the direction of an arrow as *left* or *right* by pressing the *U* or *I* key on the keyboard. Participants were first presented with a shape for 500 ms within which the arrow appeared. The shape served as context cue. Participants completed two blocks of trials: In one block the shape was a circle cueing stop trials; in the second block the shape was a square cueing double-response trials. The order of blocks was counterbalanced. In 30% of the trials, the context cue turned bold (signal trial) for 250 ms. For stop-signals, participants had to inhibit their response to categorize the arrow. For double-response trials, participants had to categorize the arrow and additionally press the space bar. The arrow disappeared after participants made their choice or after 1,500 ms. The inter-trial interval was 250 ms. For double-response trials, the frame randomly turned bold after a delay of 100, 250, or 400 ms (stimulus onset asynchrony, SOA). SOA for stop-signal trials followed a staircase tracking procedure (Verbruggen, Chambers, & Logan, 2013): SOA started at 250 ms; when inhibition was successful, SOA increased by 50 ms; when inhibition was unsuccessful, SOA decreased by 50 ms.

We instructed participants that sometimes it would be impossible to be successful on stop-signal trials, but that they should not wait for the shape to turn bold and should categorize as quickly and accurately as possible. Each block consisted of 120 trials, each preceded by 32 practice trials. During the last 10 practice trials of each block, the notification condition received three notifications. The dependent measures were SSRT (a measure of response inhibition) and DRT2 (a measure of action selection). Because the probability of responding on stop-signal trials was not .50

(*M* = 0.53, *SD* = 0.11; range = .28–.89), as assumed by the mean estimation method, we calculated SSRT by subtracting the average SOA (*M* = 218.3, *SD* = 166.6, range = 25.0–822.2) from the finishing time of the stop process (integration method; see Verbruggen et al., 2013).

The context-cueing task and notification program were coded in Python, Version 2.7; notifications were sent using Twilio, a cloud-based interface to send text messages, following the code as provided by Stothart et al. (2015).

Manipulation Checks

With visibility and notifications, we did not directly manipulate the psychological state of vigilance. Therefore, we had to ensure these manipulations did, in fact, lead to vigilance. After the context-cueing task, participants answered nine items about their smartphone vigilance during the task (e.g., "My smartphone occupied my thoughts, even though I was doing the task") on a scale ranging from 1 (= *strongly disagree*) to 5 (= *strongly agree*) that we adapted from online vigilance trait items by Reinecke et al. (2017, May). If independent Bayesian *t* tests showed participants in the visibility and notifications conditions to be more vigilant than those in the control condition, we could be more confident that any effects on inhibition were indeed caused by smartphone vigilance, as posited in our hypotheses. Further, participants indicated whether their phone vibrated during the experiment, how distracting their phone was, whether their phone was in their line of sight during the experiment, and whether they touched their phone.

Additional Measures

In addition to demographic information, we assessed several personality traits that have shown to be related to smartphone use in order to describe the population and for exploratory analyses only: fear of missing out (Przybylski, Murayama, DeHaan, & Gladwell, 2013), susceptibility to boredom (Mercer-Lynn, Flora, Fahlman, & Eastwood, 2013), need to belong (Leary, Kelly, Cottrell, & Schreindorfer, 2007), and need for popularity (Santor, Messervey, & Kusumakar, 2000). We will not report on those exploratory measures. They are available on the OSF, https://osf.io/k3p54/.

Exclusion Criteria

We applied the following a priori exclusion criteria before data analyses. We did not allow participants to touch their phones in order to alleviate the presumed state of vigilance; to control such phone interaction, all sessions were recorded with webcams in the cubicle. Consequently, we excluded five participants who touched their phones during the experiment. In addition, we excluded 10 participants in the notification condition, because their phone did not vibrate even though they received the text messages, due to customized notification profiles that the experimenter could not access. Further, we excluded two participants who received SMS that were not sent by us. Following our exclusion criteria on the participant level for the context-cueing task, we excluded one participant who had a negative SSRT. Last, because categorizing the arrow was fairly easy, we excluded six participants with lower accuracy than 90% on go-trials. After applying exclusions, we slightly exceeded our maximum sample size of 50 per group (control: *n* = 51; visibility: *n* = 53; notification: *n* = 50), due to our randomization procedure.

On the trial level, we excluded RTs 3 *SD* above or below the respective mean on go-trials on the SST (1.11%) and DRT (1.59%), as well as on the second response of double-response trials (0.67%). Last, we excluded RTs in go-trials below 200 ms (0.86%).

Results

We conducted all Bayesian analyses with JASP (JASP Team, 2017). All *t* tests are two-sided unless otherwise specified, with the standard JASP Cauchy prior. Within JASP, we also conducted robustness checks with different priors. A robustness check is used to examine how the BF changes if one has a different prior beliefs about the effect size (Wagenmakers et al., 2018).

Preregistered Analyses

Manipulation Checks

As manipulation checks, we asked participants whether their phone was in their line of sight throughout the entire experiment. As expected, all participants in the control condition said their phone was not in their line of sight. The majority of participants in the visibility condition (81%) and the notification condition (86%) indicated the same. Although from our video recordings it was clear that phones were right next to the participants' dominant hand, apparently some participants defined their line of sight strictly as the monitor.

In addition, we asked participants whether their phone vibrated during the experiment. As expected, nobody in the control condition perceived a vibration; similarly, nobody except one participant perceived a vibration in the visibility condition. We checked the participant's video again, but could not hear a vibration. Furthermore, everybody in the notification condition perceived the vibration.

Table 1. Bayes Factors (BF) for all hypothesized group comparisons

	Groups compared					
	Control–Visibility		Control–Notification		Visibility–Notification	
Variable	BF_{10}	BF_{01}	BF_{10}	BF_{01}	BF_{10}	BF_{01}
Distraction	32.65	0.03	3.61e + 16	2.77e − 17	1.06e + 9	9.43e − 10
Vigilance	37.50	0.03	3.14e + 7	3.18e-8	97.11	0.01
SSRT	0.43	2.32	0.21	4.76	0.42	2.36
DRT2	0.21	4.81	0.21	4.76	0.21	4.80

Note. SSRT = stop-signal reaction time. DRT2 = double-response reaction time.

Last, nobody of the final sample indicated that they touched their phone.

Further, when asked on a visual analogue scale ranging from 0 to 100 how distracting the phone was during the task, we found the expected pattern, such that those in the control group reported close to no distraction (M = 1.29, SD = 8.56), those in the visibility condition minimum distraction (M = 10.53, SD = 17.32), and those in the notification condition considerable distraction (M = 43.10, SD = 24.68). All of these differences among groups were more plausible under the alternative hypothesis than under the null model (all $BF_{10} > 32$, $d > .67$), with medium to large effect sizes, suggesting participants indeed perceived our manipulation as distracting (see Table 1).

Finally, we tested whether our manipulations induced vigilance. Overall, vigilance was below the midpoint of the 5-point scale and skewed toward the lower end (M = 1.60, SD = 0.66). As expected, vigilance was lowest in the control condition (M = 1.22, SD = 0.44), followed by the visibility condition (M = 1.56, SD = 0.56) and the notification condition (M = 2.03, SD = 0.69). Bayesian independent t tests indicated that the data were more likely under the alternative hypothesis of a difference between groups than under the null hypothesis: control-visibility: BF_{10} = 37.50, 95% CI = [−1.03–−.24], d = −.68; control-notification: BF_{10} = 3.14e + 7, 95% CI = [−1.78–−.91], d = −1.40; visibility-notification: BF_{10} = 97.11, 95% CI = [.31–1.08], d = .75. All BFs displayed strong to extreme evidence (Lee & Wagenmakers, 2013) with medium to large effect sizes in favor of the alternative hypothesis (see Table 1).

Overall, our manipulation checks showed that our manipulation was successful, with participants being aware of their phones when in the visibility or notification condition, perceiving it as more distracting and experiencing more vigilance. Crucially, participants in the notification condition did receive and notice the text messages we sent.

Confirmatory Analyses Context-Cueing Task

Inspecting the context-cueing task, participants almost never missed the second response in the DRT (> 99%), and overall accuracy for all conditions was almost identical (all > 97%). Overall SSRT (M = 226.8, SD = 59.8, range = 20.2–337.1) was in a similar range as previous work (e.g., Verbruggen & Logan, 2009). As expected, overall DRT2 was much higher (M = 729.3, SD = 80.4, range = 584.4–1,039.2).

Next, we tested our hypotheses on task performance (see Table 1). H_{1a} stated that the visibility condition would result in higher SSRT than the control condition. Contrary to our expectations, SSRT was comparable in the control condition (M = 232.1, SD = 51.3) and visibility condition (M = 216.5 SD = 70.8), with the BF indicating that the data were about twice (BF_{01} = 2.32, 95% CI = −.15–.60, d = .25) as likely under the null hypothesis than under the alternative hypothesis, which qualifies as inconclusive evidence (Lee & Wagenmakers, 2013). Inspecting Figure 1 (upper panel), the robustness check shows that even widening the prior distribution to assign less mass to a null effect does not substantially increase the BF. In addition, the sequential analysis perpetuates the inconclusive nature of the finding, as the BF hovers around 1, indicating the data are equally likely under the null and the alternative hypothesis.

H_{1b} stated that the notification condition would result in higher SSRT than the control condition. Surprisingly, SSRT in the notification condition (M = 232.3, SD = 54.8) was almost identical with that in the control condition; indeed, the data were about five times (BF_{01} = 4.76, 95% CI = −.37–−.36, d = −.004) more likely under a model assuming no difference between the conditions than under the alternative hypothesis, which qualifies as moderate evidence. The robustness check in Figure 1 (middle panel) displays an increase in evidence for the null hypothesis as less mass is assigned to zero. Likewise, the sequential analysis supports evidence for the null hypothesis, as the BF continually increases.

Last, we also explored whether there were differences in SSRT between the visibility and notification condition. Again, the difference between the two conditions was inconclusive; the data were about twice as likely under the null hypothesis as under the alternative hypothesis of an effect (BF_{01} = 2.36, 95% CI = −.14–.60, d = .25). As shown in Figure 1 (lower panel), the finding can be classified as inconclusive, since even giving less prior

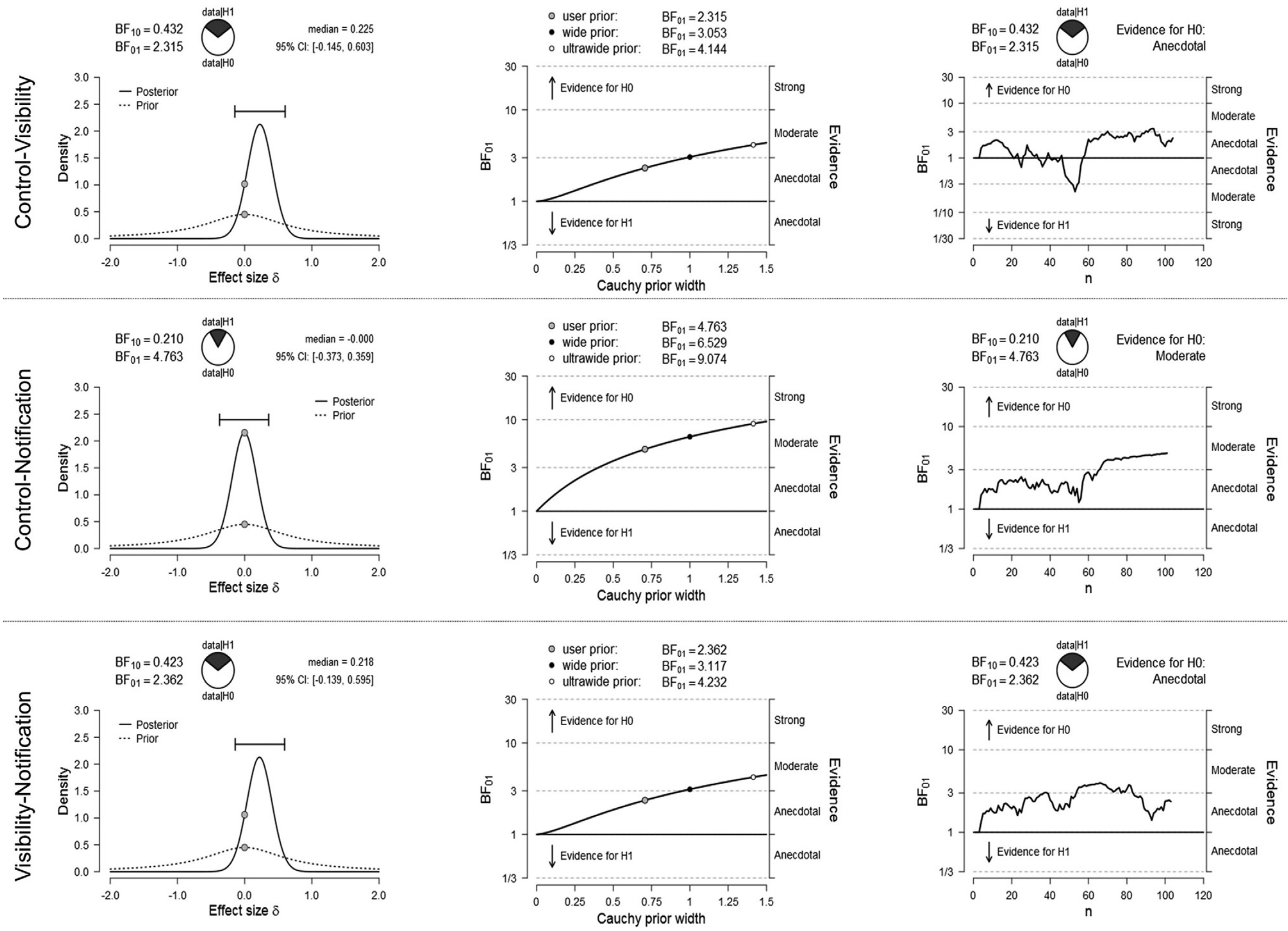

Figure 1. Prior and posterior distribution (left), Bayes Factor robustness check (middle), and sequential analysis (right) for all independent Bayesian *t* tests on SSRT. Upper panel (A) compares control condition with visibility condition. Middle panel (B) compares control with notification. Lower panel (C) compares visibility with notification. SSRT = stop-signal reaction time.

plausibility to the null hypothesis does not increase support for the null substantially. Just as with H_{1a}, the sequential analysis displays BFs that hover around 1.

Because smartphone vigilance might not have an effect on response inhibition, but rather on action selection, we investigated whether there were differences between the conditions on DRT2. Comparing the control condition (M = 728.8, SD = 80.4) with the visibility condition (M = 729.9, SD = 73.5) showed moderate support for the null hypothesis (BF_{01} = 4.81, 95% CI = −.38–.35, d = −.02), which steadily increased with wider prior distributions and a clear trend in the BFs toward H_0 for the sequential analysis.

Similarly, DRT2 between the control condition and notification condition (M = 729.2, SD = 88.6) was extremely similar, again with moderate support for the null hypothesis of no difference (BF_{01} = 4.76, 95% CI = [−.36–.37], d = −.005). Widening the prior distribution again increased support for the null hypothesis; the sequential analysis displayed a trend toward H_0 as well.

Last, comparing the visibility and notification conditions, the data were about five times (BF_{01} = 4.80, 95% CI = −.37–.35, d = −.01) more likely under the null hypothesis of no difference, indicating moderate support. As before, increasing the prior width increased support for H_0, and the sequential analysis demonstrated a clear trend toward H_0 as well.

Exploratory Analyses Context Cueing-Task

In accordance with our preregistration, we investigated an alternative explanation should we not find the expected effects, namely, proactive control. Previous work has shown that reaction times on go-trials (GoRTs) are slower in stop-signal blocks compared with double response blocks (e.g., Verbruggen & Logan, 2009). This effect is assumed to reflect proactive control in order to avoid failing to stop in time. Indeed, and consistent with this work, GoRTs were higher in the SST (M = 466.9, SD = 168.8) than in the DRT blocks (335.7, SD = 43.3; Bayesian paired-sample *t* test: BF_{10} = 2.64e + 15, 95% CI = [.61–.98], *d* = .81), reflected on the overall positive difference score (*M* = 131.1, *SD* = 162.7).

Similarly, we might expect enhanced proactive control in the notification condition compared with the control condition: When participants proactively control their responses toward their phone, they should become slower on GoRTs even when the task does not require control, because the proactive control aimed at their phones also slows GoRTs. This would mean that in the notification condition, GoRTs in the double response block should be more similar to GoRTs in the stop block compared with this difference in the control condition.

To test this, we conducted independent Bayesian *t* tests between the notification condition and the control condition on the difference scores between GoRTs in the stop-signal block and GoRTs in the double-response block (higher scores indicate more active proactive control). Crucially, we did not find any indication that our manipulations induced proactive control; instead, there was anecdotal to moderate evidence (BF_{01} = 3.71, 95% CI = −.50–.24, *d* = −.15) that the data were more likely under the null hypothesis than under the alternative hypothesis (control: *M* = 114.3, *SD* = 140.2; notification: *M* = 138.7, *SD* = 184.8).

Nonpreregistered Analyses

Previous research (Stothart et al., 2015) sent notifications throughout the entire block, not just during the practice trials. To see whether we could replicate the effect, we compared accuracy on no-signal trials in the last 10 trials of the practice block (i.e., when notifications came in) between the notification condition and the control condition. Even though accuracy during these trials was slightly lower in the notification condition (*M* = 95.7, *SD* = 6.1) than in the control condition (*M* = 96.8, *SD* = 6.1), the data were more likely under the null hypothesis (BF_{01} = 3.27, 95% CI = −.21–.53, *d* = .18). This constitutes anecdotal to moderate evidence against a distracting effect of the notifications when they came in.

Last, to explore whether self-reported vigilance was related to response inhibition, we correlated vigilance scores with SSRT. The data did not support such a relationship; to the contrary, there was moderate evidence for the null model (BF_{01} = 6.39, 95% CI = −.23–.08, *r* = −.08).

Discussion

Contrary to our expectations, our experiment generally yielded results that support a lack of an effect of smartphone visibility and notifications on response inhibition. We can state with moderate certainty that there was no effect of the notification condition on response inhibition in our data. This lack of an effect was less pronounced when comparing the control and visibility condition, as the differences in inhibition were only slightly more likely assuming no effect. Similarly, the differences between visibility and notification provided only weak evidence for the lack of an effect. Although we collected our predefined maximum sample size, none of the BFs reached our stopping rule of BF = 6, and thus the data are not conclusive. Taken together, there is no evidence that smartphone vigilance had an effect on response inhibition; if anything, our study supports the lack of an effect.

In addition, our design allowed us to distinguish between response inhibition and action selection, which subsumes action plan updating and attention updating. Mirroring the results for inhibition, it appeared that smartphone visibility and notifications did not have an effect on action selection either. Yet, as stated earlier, no BF reached the threshold of six, and therefore the overall evidence for the lack of an effect is only moderate.

Interestingly, effects emerged very clearly on self-reported measures: Simply having a smartphone on the table increased self-reported vigilance, such as the urge of participants to check their phone or their thoughts about what was going on with their phone. This vigilance was even higher when people received notifications but could not check them. Similarly, visibility and notifications were perceived as very distracting. Consequently, participants were aware of their phones and they reported both a strong urge to check it as well as cognitive preoccupation with it.

Manipulation and Task

When comparing self-reported and behavioral data, participants indicated that they felt like smartphones were distracting and made them vigilant. However, our results imply they did not, in fact, affect EF, neither response inhibition nor action selection. In our view, there are two possible methodological explanations of why we did not find effects of smartphone vigilance on inhibition.

First, participants may not have been vigilant. That is, participants might have guessed that their phone was supposed to be distracting, and, consequently, reported higher levels of distraction and vigilance because they felt they were expected to, but did not experience this state. Although we cannot rule out such an explanation, participants were not aware of the other conditions; it seems unlikely that participants in the visibility condition reported much higher vigilance than the control condition, but lower than the notifications condition as a demand artifact. Moreover, if demand artifacts were an issue, it is not so clear why participants did not perform worse on the task (e.g., by making more errors), given that accuracy in the three conditions was close to identical. Furthermore, smartphone visibility and notifications were manipulated in a controlled and objective manner. Therefore, we believe it is reasonable to assume our manipulation did indeed induce vigilance.

Second, low validity of our inhibition measure could also account for our null-findings. However, all parameters we found are similar to those of previous research or follow logically from the premises of the task. First, overall SSRT and accuracy were within the range of what previous research found that used a relatively easy categorization task such as in our study (Verbruggen & Logan, 2009), and SSRT was slightly lower than previous research employing a more complicated task (Verbruggen et al., 2010). Second, because the DRT does not require stopping and, consequently, proactive control, GoRTs were higher on the SST than on the DRT, which adds to the validity of the measure (Verbruggen & Logan, 2009). Furthermore, the probability to respond on signal-trials as well as its range were comparable to previous work, which attests to the adequacy of the staircase procedure we employed (Verbruggen et al., 2010; Verbruggen & Logan, 2009). Overall, then, it appears unlikely the measurement validity of the task was responsible for the lack of an effect.

Resources, Automatized Vigilance, and Personality Moderators

In addition to methodological explanations, we believe there are theoretical accounts for why vigilance did not affect inhibition. First, the effect of smartphone vigilance on response inhibition could have been masked by increased performance due to increased recruitment of cognitive resources. Two related theoretical accounts could explain such enhanced control. From an avoidance cues account (Koch, Holland, & van Knippenberg, 2008), not being allowed to touch one's phone could have served as a cue to enter a state of alertness, recruiting more cognitive resources. Therefore, it is possible that the distraction of their phones interfered with inhibitory processes, while the additional resources recruited because of the avoidance mindset offset this interference. From the inhibitory spillover account (Tuk, Zhang, & Sweldens, 2015), inhibitory capacity is not specific to one domain; rather, if one has to inhibit a response in one domain, it facilitates inhibition in an unrelated domain, as long as both processes happen simultaneously. As such, not giving in to the urge to check one's phone or think about it constitutes inhibition in one domain, which could facilitate response inhibition during the stop-signal task. Just as with avoidance cues, this spillover could have counteracted the interfering effect of smartphone vigilance. However, under both frameworks, the smartphone manipulations should have also facilitated proactive control, for which we found no evidence.

Second, at this point of smartphone saturation and constant connectivity, users may have grown accustomed to being vigilant at all times to a degree that it does not affect executive control anymore. Supporting such a position, we observed overall rather low levels of vigilance for the entire sample, below the midpoint of the scale, which could be an indication that participants were not overly vigilant. Instead, smartphone vigilance could have become automatized. As more recent work suggests, smartphone or online vigilance has likely become the norm among users (Klimmt, Hefner, Reinecke, Rieger, & Vorderer, 2018). Evidence for such an assumption comes from Reinecke et al. (2017, May), who also reported means close to or below the midpoint of the scale. Thus, the vigilance we induced might have been strong enough to manifest itself on a self-reported level in the expected pattern, but it might be too automatized to affect behavior (Potter, 2011).

Third, expanding the point of automatized vigilance, it is likely that the effect of vigilance depends on personality factors. For example, users who have learnt to benefit from the constant social support their smartphones provide them might experience more intense vigilance that impedes performance (Reinecke, 2018). Similarly, users with a high fear of missing out may be particularly susceptible to smartphone cues (Przybylski et al., 2013). However, it is unclear whether such personality characteristics would raise the threshold of automatized vigilance or lower it. We invite researchers to use the data on personality traits we have collected and explore possible moderators. Moreover, there is a need for research examining how much variation in vigilance there is between different users and how those users differ on other personality traits.

Finally, it is possible that vigilance influences certain executive control components such as sustained attention, but not others such as response inhibition (e.g., Stothart et al., 2015; Thornton et al., 2014). Future research may examine this possibility systematically.

Implications and Conclusion

We investigated the assumption that smartphones interfere with response inhibition, using a large sample with an economic, flexible sampling design in a highly controlled laboratory experiment with a novel, innovative manipulation. We were unable to obtain evidence for the assumption that smartphones interfere with the inhibition process. Even though a lot of users complain that their phones put them in a state of alertness, which we termed *smartphone* *vigilance*, their phones did indeed make them feel vigilant, but did not interfere with EF. Comparing our findings with research demonstrating a negative effect of smartphone use, for example, in the form of multitasking (van der Schuur et al., 2015), shows that there is a need for subsequent studies investigating the difference between the mere presence and actual use of smartphones. As participants in our study were not allowed to touch their phones, restricting smartphone access appears to be beneficial to performance, which lends support to policies banning smartphone use in class. To conclude, our findings call for a better understanding of the conditions under which smartphones impair performance.

Acknowledgments

We thank Thabo van Woudenberg for his help and for proofreading the R code. We also thank Zhang Chen and Cary Stothart for sharing their scripts.

Research Transparency Statement

The authors are willing to share their data, analytics methods, and study materials with other researchers. The material is available https://osf.io/k3p54/

References

Bayer, J. B., Campbell, S. W., & Ling, R. (2015). Connection cues: Activating the norms and habits of social connectedness. *Communication Theory*,1–22. https://doi.org/10.1111/comt.12090

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences, 21*(4), 327–336. https://doi.org/10.1016/j.lindif.2011.01.007

bitkom. (2015). *Zahl der verschickten SMS sinkt um 40 Prozent* [Number of sent SMS decreases by 40%]. Retrieved from https://www.bitkom.org/Presse/Presseinformation/Zahl-der-verschickten-SMS-sinkt-um-40-Prozent.html

Calderwood, C., Ackerman, P. L., & Conklin, E. M. (2014). What else do college students "do" while studying? An investigation of multitasking. *Computers and Education, 75*, 19–29. https://doi.org/10.1016/j.compedu.2014.02.004

Chein, J. M., Wilmer, H. H., & Sherman, L. E. (2017). Smartphones and cognition: A review of research exploring the links between mobile technology habits and cognitive functioning. *Frontiers in Psychology, 8*, 1–16. https://doi.org/10.3389/fpsyg.2017.00605

Chen, Q., & Yan, Z. (2016). Does multitasking with mobile phones affect learning? A review. *Computers in Human Behavior, 54*, 34–42. https://doi.org/10.1016/j.chb.2015.07.047

Chun, H., Lee, H., & Kim, D. (2012). The integrated model of smartphone adoption: Hedonic and utilitarian value perceptions of smartphones among Korean college students. *Cyberpsychology, Behavior, and Social Networking, 15*(9), 473–479. https://doi.org/10.1089/cyber.2012.0140

Cserjési, R., Luminet, O., Poncelet, A.-S., & Lénárd, L. (2009). Altered executive function in obesity. Exploration of the role of affective states on cognitive abilities. *Appetite, 52*(2), 535–539. https://doi.org/10.1016/j.appet.2009.01.003

Diamond, A. (2014). Executive functions. *Annual Review of Clinical Psychology, 64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Friedman, N. P., Miyake, A., Young, S. E., Defries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General, 137*(2), 201–225. https://doi.org/10.1037/0096-3445.137.2.201

Hadlington, L. J. (2015). Cognitive failures in daily life: Exploring the link with Internet addiction and problematic mobile phone use. *Computers in Human Behavior, 51*, 75–81. https://doi.org/10.1016/j.chb.2015.04.036

Hall, J. A., & Baym, N. K. (2012). Calling and texting (too much): Mobile maintenance expectations, (over)dependence, entrapment, and friendship satisfaction. *New Media & Society, 14*(2), 316–331. https://doi.org/10.1177/1461444811415047

Hartanto, A., & Yang, H. (2016). Is the smartphone a smart choice? The effect of smartphone separation on executive functions. *Computers in Human Behavior, 64*, 329–336. https://doi.org/10.1016/j.chb.2016.07.002

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences, 16*(3), 174–180. https://doi.org/10.1016/j.tics.2012.01.006

Inzlicht, M., & Berkman, E. (2015). Six questions for the resource model of control (and some answers). *Social and Personality Psychology Compass, 9/10*, 511–524. https://doi.org/10.1111/spc3.12200

JASP Team. (2017). *JASP*. (Version 0.8.1.1) [Computer software]

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review, 17*(3), 213–233. https://doi.org/10.1007/s11065-007-9040-z

Karapanos, E., Teixeira, P., & Gouveia, R. (2016). Need fulfillment and experiences on social media: A case on Facebook and WhatsApp. *Computers in Human Behavior, 55*, 888–897. https://doi.org/10.1016/j.chb.2015.10.015

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). New York, NY: Routledge.

Koch, S., Holland, R. W., & van Knippenberg, A. (2008). Regulating cognitive control through approach-avoidance motor actions. *Cognition, 109*(1), 133–142. https://doi.org/10.1016/j.cognition.2008.07.014

Leary, M. R., Kelly, K. M., Cottrell, C. A., & Schreindorfer, L. S. (2007). *Individual differences in the need to belong: Mapping the nomological network*. Unpublished Manuscript. Durham, NC: Duke University.

Lee, M. D., & Wagenmakers, E.-J. (2013). *Bayesian cognitive modeling: A practical course*. New York, NY: Cambridge University Press.

Levine, L. E., Waite, B. M., & Bowman, L. L. (2013). Use of instant messaging predicts self-report but not performance measures of inattention, impulsiveness, and distractibility. *Cyberpsychology, Behavior and Social Networking, 16*(12), 898–903. https://doi.org/10.1089/cyber.2012.0504

Logan, G. D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.

Mercer-Lynn, K. B., Flora, D. B., Fahlman, S. A., & Eastwood, J. D. (2013). The measurement of boredom: Differences between existing self-report scales. *Assessment, 20*(5), 585–596. https://doi.org/10.1177/1073191111408229

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Oulasvirta, A., Rattenbury, T., Ma, L., & Raita, E. (2012). Habits make smartphone use more pervasive. *Personal and Ubiquitous Computing, 16*(1), 105–114. https://doi.org/10.1007/s00779-011-0412-2

Pew Research Center. (2015). *US smartphone use in 2015*. Retrieved from http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

Potter, W. J. (2011). Conceptualizing mass media effect. *Journal of Communication, 61*(5), 896–915. https://doi.org/10.1111/j.1460-2466.2011.01586.x

Przybylski, A. K., Murayama, K., DeHaan, C. R., & Gladwell, V. (2013). Motivational, emotional, and behavioral correlates of fear of missing out. *Computers in Human Behavior, 29*, 1841–1848. https://doi.org/10.1016/j.chb.2013.02.014

Przybylski, A. K., & Weinstein, N. (2013). Can you connect with me now? How the presence of mobile communication technology influences face-to-face conversation quality. *Journal of Social and Personal Relationships, 30*(3), 237–246. https://doi.org/10.1177/0265407512453827

Reinecke, L. (2018). POPC and well-being: A risk-benefit analysis. In P. Vorderer, D. Hefner, L. Reinecke, & C. Klimmt (Eds.), *Permanently online, permanently connected. Living and communication in a POPC world* (pp. 233–243). New York, NY: Routledge.

Reinecke, L., Klimmt, C., Meier, A., Reich, S., Hefner, D., Knop-Hülß, K., . . . Vorderer, P. (2017, May). *Permanently online and permanently connected: Development and validation of the online vigilance scale*. Paper presented at the 67th Annual Conference of the International Communication Association (ICA), San Diego, USA.

Roberts, J. A., & Pirog, S. F. (2013). A preliminary investigation of materialism and impulsiveness as predictors of technological addictions among young adults. *Journal of Behavioral Addictions, 2*(1), 56–62. https://doi.org/10.1556/JBA.1.2012.011

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS One, 8*(1), e54402. https://doi.org/10.1371/journal.pone.0054402

Santor, D. A., Messervey, D., & Kusumakar, V. (2000). Measuring peer pressure, popularity, and conformity in adolescent boys and girls: Predicting school performance, sexual attitudes, and substances. *Journal of Youth and Adolescence, 29*(2), 163–182.

Schönbrodt, F. D., Wagenmakers, E.-J., Zehetleitner, M., & Perugini, M. (2017). Sequential hypothesis testing with Bayes factors: Efficiently testing mean differences. *Psychological Methods, 22*(2), 322–339. https://doi.org/10.1037/met0000061

Seo, M., Kim, J.-H., & David, P. (2015). Always connected or always distracted? ADHD symptoms and social assurance explain problematic use of mobile phone and multicommunicating. *Journal of Computer-Mediated Communication, 20*, 667–681. https://doi.org/10.1111/jcc4.12140

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. https://doi.org/10.1016/j.jenvp. 2009.03.001

Smetaniuk, P. (2014). A preliminary investigation into the prevalence and prediction of problematic cell phone use. *Journal of Behavioral Addictions, 3*(1), 41–53. https://doi.org/10.1556/JBA.3.2014.004

Soror, A. A., Hammer, B. I., Steelman, Z. R., Davis, F. D., & Limayem, M. M. (2015). Good habits gone bad: Explaining negative consequences associated with the use of mobile phones from a dual-systems perspective. *Information Systems Journal, 25*, 403–427. https://doi.org/10.1111/isj.12065

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), 893–897. https://doi.org/10.1037/xhp0000100

Süddeutsche Zeitung. (2015). *"Smombie" ist das Jugendwort des Jahres* ["Smombie" is youth word of the year]. Retrieved from http://www.sueddeutsche.de/kultur/deutsche-sprache-smombie-ist-das-jugendwort-des-jahres-1.2735599

Thornton, B., Faires, A., Robbins, M., & Rollins, E. (2014). The mere presence of a cell phone may be distracting. *Social Psychology, 45*(6), 479–488. https://doi.org/10.1027/1864-9335/a000216

Tuk, M. A., Zhang, K., & Sweldens, S. (2015). The propagation of self-control: Self-control in one domain simultaneously improves self-control in other domains. *Journal of Experimental Psychology: General, 144*(3), 639–654. https://doi.org/10.1037/xge0000065

van der Schuur, W. A., Baumgartner, S. E., Sumter, S. R., & Valkenburg, P. M. (2015). The consequences of media multitasking for youth: A review. *Computers in Human Behavior, 53*, 204–215. https://doi.org/10.1016/j.chb.2015.06.035

Verbruggen, F., Aron, A. R., Stevens, M. A., & Chambers, C. D. (2010). Theta burst stimulation dissociates attention and action updating in human inferior frontal cortex. *Proceedings of the National Academy of Sciences of the United States of America, 107*(31), 13966–13971. https://doi.org/10.1073/pnas.1001957107

Verbruggen, F., Chambers, C. D., & Logan, G. D. (2013). Fictitious inhibitory differences: How skewness and slowing distort the estimation of stopping latencies. *Psychological Science, 24*(3), 352–362. https://doi.org/10.1177/0956797612457390

Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences, 12*(11), 418–424. https://doi.org/10.1016/j.tics.2008.07.005

Verbruggen, F., & Logan, G. D. (2009). Proactive adjustments of response strategies in the stop-signal paradigm. *Journal of Experimental Psychology. Human Perception and Performance, 35*(3), 835–854. https://doi.org/10.1037/a0012726

Verbruggen, F., Stevens, T., & Chambers, C. D. (2014). Proactive and reactive stopping when distracted: An attentional account. *Journal of Experimental Psychology: Human Perception and Performance, 40*(4), 1295–1300. https://doi.org/10.1037/a0036542

Vorderer, P., & Kohring, M. (2013). Permanently online: A challenge for media and communication research. *International Journal of Communication, 7*, 188–196. https://doi.org/1932-8036/2013FEA0002

Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of *p* values. *Psychonomic Bulletin & Review, 14*(5), 779–804. https://doi.org/10.3758/BF03194105

Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., . . . Morey, R. D. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin and Review, 25*(1), 35–57. https://doi.org/10.3758/s13423-017-1343-3

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 50*(3), 433–441. https://doi.org/10.1518/001872008X312152

Received September 26, 2016
Revision received May 8, 2018
Accepted May 23, 2018
Published online October 1, 2018

Niklas Johannes
Behavioural Science Institute
Radboud University
Postbus 9104
6500 HE Nijmegen
The Netherlands
n.johannes@bsi.ru.nl

Niklas Johannes (MSc, 2015) is a PhD candidate at the Behavioural Science Institute, Radboud University, The Netherlands. He researches the role of mobile communication technologies in cognitive and behavioral processes. In particular, he is interested in the effects of being constantly connected.

Harm Veling (PhD, 2007) is Assistant Professor at the Behavioural Science Institute, Radboud University, The Netherlands. His research focuses on acquiring new knowledge on basic processes of behavior regulation, and the development of effective behavior change interventions targeting behavior regulatory problems. The emphasis is on understanding and changing impulsive processes that may cause behavior regulatory problems.

Thijs Verwijmeren (PhD, 2014) is Assistant Professor in the Department of Social and Cultural Psychology at the Behavioural Science Institute, Radboud University, The Netherlands. Some of his research and teaching topics include social influence and subliminal advertising.

Moniek Buijzen (PhD, 2003) is Professor and Chair of Communication Science, Behavioural Science Institute (BSI), Radboud University, The Netherlands. Her research focuses on young (media) consumers within the paradigm of positive communication science. Addition, she is co-initiator of Bitescience.com, an online portal for worldwide academic research on young (media) consumers.

