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OBSERVATION

The Attentional Cost of Receiving a Cell Phone Notification

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It is well documented that interacting with a mobile phone is associated with poorer performance on concurrently performed tasks because limited attentional resources must be shared between tasks. However, mobile phones generate auditory or tactile notifications to alert users of incoming calls and messages. Although these notifications are generally short in duration, they can prompt task-irrelevant thoughts, or mind wandering, which has been shown to damage task performance. We found that cellular phone notifications alone significantly disrupted performance on an attention-demanding task, even when participants did not directly interact with a mobile device during the task. The magnitude of observed distraction effects was comparable in magnitude to those seen when users actively used a mobile phone, either for voice calls or text messaging.

Keywords: cell phones, text messaging, distraction, mind wandering, attention, prospective memory

Supplemental materials: http://dx.doi.org/10.1037/xhp0000100.supp

Mobile phones have become ubiquitous in modern culture; an estimated 91% of American adults report owning a mobile phone, and an increasing proportion of these are "smartphones," which can also be used to access e-mail and social media, download music, and watch videos (Duggan, 2013). A common concern is that these multiuse electronic devices are a significant distractor and that many users, particularly adolescents and young adults, do not make judicious decisions about when it is safe and appropriate to use a mobile device (National Highway Traffic Safety Administration, 2012, 2013). In addition to the well-known effects of cellular phone−related distraction on driving performance, which are found whether or not drivers use a hands-free device (Caird, Johnston, Willness, Asbridge, & Steel, 2014; Horrey & Wickens, 2006; National Highway Traffic Safety Administration, 2013; Strayer & Johnston, 2001; Strayer, Drews, & Johnston, 2003), problematic use of mobile phones has also been documented in many other settings (Katz-Sidlow, Ludwig, Miller, & Sidlow, 2012; T. Smith, Darling, & Searles, 2011; Tindell & Bohlander, 2012).

Public information campaigns intended to deter problematic mobile phone use often emphasize waiting to respond to messages and calls. However, it may be that waiting, too, carries a significant attention cost. This yet unexamined source of phone-related distraction is the focus of the current study. There is good reason to suspect that waiting to respond to a call or text message may itself disrupt attention performance. First, work in prospective memory has found that simply remembering to perform some action in the future is sufficient to disrupt performance on an unrelated concurrent task (e.g., R. E. Smith, 2003). In some sense, noticing that one has received a call or text represents a new prospective memory demand; if one receives a message or call, most prefer to respond promptly. Second, a large body of work has found that task-irrelevant thoughts, even in cases when the individual appears to be attending to the task at hand, disrupt performance on a wide range of tasks (Smallwood & Schooler, 2006; Schooler et al., 2011), including driving (Cowley, 2013; He, Becic, Lee, & McCarley, 2011; Lemercier et al., 2014). It is reasonable to expect that a notification from a mobile device, when noticed by the user, can give rise to task-irrelevant thoughts concerning the message's source or content. While message notifications themselves may be very brief, message-related thoughts prompted by these notifications likely persist much longer.

To address whether receiving, but not responding to, cellular notifications carries an attention cost, we conducted a study to compare performance of participants who received cellular notifications and those who did not using an attention-demanding task, the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The SART, which requires quick responses to target items while also withholding responses to infrequent nontarget items, has been shown to be a sensitive measure of sustained attention, and performance on the task correlates with self-reported instances of mind wandering (e.g., Cheyne, Solman, Carriere, & Smilek, 2009).

Method

Participants

Participants were 212 undergraduate students enrolled in psychology courses at Florida State University. Participants were

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randomly assigned to one of three groups: call, text message, or no notification control. Data from 46 participants were excluded from analysis, the most common reasons for which being that the experimenter noticed the participant looking at or handling their phone ($n = 20$), the participant's phone was turned off during the study ($n = 13$), and missing data ($n = 9$).[1] Analyses included data from the remaining 166 participants: 57 in the text messaging group (39 females, 11 males, 7 refused; $M_{age} = 19.37$ years, $SD = 1.65$), 50 in the call group (35 females, 12 males, 3 refused; $M_{age} = 19.48$ years, $SD = 2.19$), and 59 in the no notification group (30 females, 19 males, 10 refused; $M_{age} = 20.00$ years, $SD = 2.46$).

Stimuli and Apparatus

Sustained attention to response task. In the SART (see Figure 1), numbers were presented at a rate of about one item per second, and participants were instructed to press a key every time a number (digits 1−9) was presented (target) unless the number was 3 (nontarget). The SART consisted of three blocks: An 18-trial practice block, which included accuracy feedback, and two additional blocks of 360 trials each, which included no accuracy feedback. Each unique digit appeared 40 times per block, and presentation order was randomized for each participant. The font size at which digits were presented was varied between trials, randomly selected from a set of five possible font heights, with each size used 72 times per block: 1.20, 1.80, 2.35, 2.50, or 3.00 cm.[2]

Mobile phone notifications. Participants in the two notification conditions received either calls or text messages during the second block of the SART. To synchronize the timing of the SART trials with the timing of the text messages, the SART included an integrated script that sent text messages or made calls to participants' phones. Both the notification program and the SART were coded in Python, Version 2.7, and used functions from the PsychoPy package (Peirce, 2007). Text messages and phone calls were sent using the Twilio application programming interface (Twilio, 2014a, 2014b).

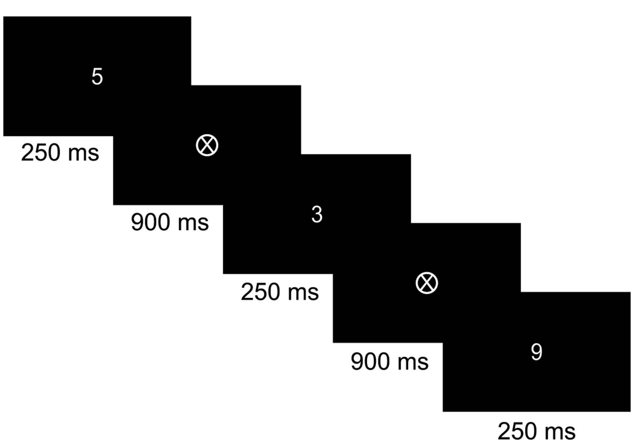

Figure 1. The Sustained Attention to Response Task. Participants were instructed to press a key when a number is flashed, except if the number was 3. Participants could make a keyboard response at any time during the trial.

A unique and important aspect of our experimental task, which differs from previous studies of cellular phone−induced distraction, is that notifications were sent to participants' own phones, but participants were not made aware of this, or that the experiment's purpose related to cellular phones or distraction, until after the task. We chose this approach because we believe that a large part of cellular notifications' potential for distraction comes from the fact that messages contain personally relevant content, which would not be true of notifications participants knew were part of an experiment[3]. To avoid arousing suspicion about the experiment's true purpose, participants received no instructions regarding their phones at the beginning of the experimental session, nor were they instructed to refrain from checking their phones during the SART. If a participant did look at or manipulate their phone during the SART, the experimenter recorded the number of times this occurred during the session.

Procedure

Participants first completed an electronic check-in sheet, which included fields for their phone number, email, and other demographic and health information. Participants in the text message and call conditions received either text messages or phone calls during the second block of the SART, and participants in the no notification group did not receive notifications, though they may have received personal messages during that time. To ensure that experimenters were blind to participant condition, the experiment program managed condition assignment.

The experimenter remained in the room during the entire session but was seated behind the participant, so that the experimenter had a clear view of the screen but was not in the participant's field of view. SART instructions, which were displayed on screen and were identical for all three groups, instructed participants to give equal importance to both accuracy and speed. Immediately following the instructions, participants completed a brief practice block, then began the first block of the SART. Participants in both groups were given a 1-min break before beginning the second block and were asked to remain in the room during the break.

During the second block of the SART, participants in the two notification conditions received either text messages or calls placed to the phone number they provided at the beginning of the session. The first notification was sent after Trial 1, a second was sent after the 91th trial, a third was sent after the 181th trial, and

[1] We excluded any participant who showed overt signs of not attending to the SART task because we were interested in the performance of participants who were attending to the task but may have been distracted by thoughts about the message or call content. Other work has documented performance costs associated with interacting with mobile devices, so we did not want to duplicate that effort in the current study. Our results did not change when all participants were included in the analyses. A table with a full list of reasons participants were excluded is included in the supplemental materials, as well as analysis results when all participants were included.

[2] This was also done in the original version of the SART used by Robertson et al., 1997. The purpose of the manipulation was to increase the likelihood that performance on the task required processing the numerical value of items and did not reflect a search strategy where participants looked only for a specific feature of nontarget items (3s).

[3] However, it is possible that the opposite is true.

Table 1
Results of the Mixed Effects Logistic Regression Model for Commission Errors

Variable	*B* (logit)	Wald *z*	95% CI for *B*	*p*
Intercept	−0.388	−5.221	[−0.535, −0.241]	<.001
Block 1	0.148	7.758	[0.110, 0.185]	<.001
Notifications vs. no notifications	0.014	0.264	[−0.088, 0.116]	.791
Calls vs. text messaging	0.173	1.871	[−0.009, 0.356]	.061
Block 1: Notifications vs. no notifications	0.047	3.566	[0.021, 0.073]	<.001
Block 1: calls vs. text messaging	0.033	1.367	[−0.014, 0.800]	.171

Note. The variance for the random intercepts was 0.845 (logit). CI = confidence interval.

a fourth was sent after the 271th trial, making it so that each notification was separated by 90 trials.

Following the SART, but before being debriefed, all participants completed a survey asking about their beliefs about the purpose and hypothesis of the study and then a survey regarding their text messaging behavior. At the end of the session, all participants were fully debriefed on the purpose of the study and asked what alert setting their phone had been on during the task.

Results

Analyses were run using the lme4 package in R, Version 2.14.1 (R Development Core Team, 2012; Bates, Maechler, Bolker, & Walker, 2013). Two metrics of attention performance were examined: commission errors, that is, unintended responses to nontarget items, and anticipations, which are responses with such fast reaction times (RTs) that it is likely participants responded before they were aware of what number was being displayed. Past work has found each of these measures of attention performance to be associated with task-unrelated thoughts (e.g., Cheyne et al., 2009).

A mixed-effects logistic regression using full maximum likelihood estimation was conducted to assess the effect of phone notifications on the probability of making a commission error. The full model included fixed effects of block number, notification condition, and their interaction and a random intercept for each participant (see Table 1). As in other studies using long, sustained attention tasks like the SART, the probability of errors increased between blocks, with participants making significantly more errors on the second block of trials than on the first, $\chi^2(1) = 55.97$, $p < .001$ (see Figure 2). However, and more critically, the extent to which the probability of making an error increased between blocks differed between conditions, $\chi^2(2) = 14.15$, $p < .001$, such that there was a greater increase in the probability of making an error for the text message and call conditions than the no notification condition.[4] The degree to which the probability of making an error increased between blocks did not differ significantly between the text message and call conditions, though the magnitude of the increase was larger for the call group ($d_z = 0.72$) than for the text message group ($d_z = 0.54$). When comparing each notification group with the no notification group directly, both the call group ($b = -0.17$, $SE = 0.05$, Wald $z = -3.69$, $p < .001$) and text message group ($b = 0.11$, $SE = 0.05$, Wald $z = 2.37$, $p = .02$) showed a greater block increase.

For the call condition, the state of the participant's phone was recorded for each trial (e.g., ringing, not ringing).[5] Participants' phones were ringing during 31% of trials during Block 2. If the act of noticing a notification itself is distracting, one would expect a higher rate of commission errors during trials where participants' phones were ringing. This was not the case; the probability of errors was effectively identical between trials where the participant's phone was ringing (49%) and those where it was not (51%) ($b = 0.07$, $SE = 0.11$, Wald $z = 0.66$, $p = .51$).

Another indicator of distraction on the SART is the frequency of trials with very fast RTs, which suggest that the participant is responding automatically, in pace with the SART's predictable item presentation rate. We defined fast RTs as those that fell below the 5th percentile for all RTs (<188.9 ms), which included both correct responses and commission errors. As was done for commission errors, a mixed-effects logistic regression was used to test whether there was a greater change in the likelihood of very fast RTs between blocks for the two notification conditions. Consistent

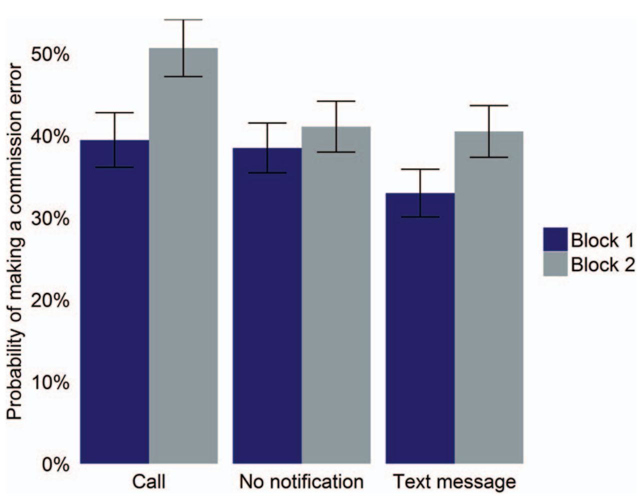

Figure 2. The probability of making a commission error by condition and block. Error bars represent 1 *SE*. See the online article for the color version of this figure.

[4] The effect of block, $\chi^2(1) = 65.35$, $p < .001$, as well as the Block × Condition interaction, $\chi^2(2) = 9.59$, $p = .008$, were virtually unchanged when analyses were run on the full sample of 212 participants, including the 46 excluded participants. The degree to which commission error rate increased between blocks was also similar in this analysis: call ($d_z = 0.63$), text message ($d_z = 0.50$), and no notification ($d_z = 0.17$).

[5] This was not possible for text messages, because the state of the receiver's phone could not be monitored with text messages. Also, the delay between when a text message is sent and when it will be received, although typically very brief, is not consistent and cannot be predicted.

Table 2
Results of the Mixed Effects Logistic Regression Model for Fast Reaction Times

Variable	*B* (logit)	Wald *z*	95% CI for *B*	*p*
Intercept	−4.099	−29.35	[−4.378, −3.827]	<.001
Block 1	0.513	31.69	[0.482, 0.545]	<.001
Notifications vs. no notifications	0.012	0.170	[−0.174, 0.207]	.865
Calls vs. text messaging	0.193	1.120	[0.147, 0.535]	.265
Block 1: Notifications vs. no notifications	0.030	2.670	[0.008, 0.052]	.008
Block 1: Calls vs. text messaging	0.085	4.210	[0.045, 0.124]	<.001

Note. The variance for the random intercepts was 2.977 (logit). CI = confidence interval.

with results for commission errors, the likelihood of very fast RTs increased between blocks and the magnitude of this increase differed between groups, $\chi^2(2) = 25.41$, $p < .001$. However, for this measure, the increase was larger for the call group than the text message group, suggesting that call notifications were more distracting than text notifications (see Table 2; Figure 3). When comparing each notification group with the no notification group directly, the call group ($b = -0.18$, $SE = 0.04$, Wald $z = -4.49$, $p < .001$) but not the text message group ($b = 0.01$, $SE = 0.04$, Wald $z = 0.14$, $p = .89$) showed a greater block increase.

Discussion

The current study found evidence that cellular notifications, even when one does not view or respond to messages or answer calls, can significantly damage performance on an attention-demanding task.[6] In fact, the degree to which commission errors increased between blocks for both the call ($d_z = 0.72$) and text message ($d_z = 0.54$) conditions was similar in magnitude to the decrease in performance between distracted and nondistracted conditions in studies of distracted driving (Caird et al., 2014; Horrey & Wickens, 2006). Though not directly assessed in our study, we believe that what underlies this effect is the tendency for cellular notifications to prompt task-irrelevant thoughts, or mind wandering, which persist beyond the duration of the notifications themselves. Because our analysis included only participants who did not directly interact with their mobile phone, either by looking at or manipulating the phone, and the degree to which error rate increased between blocks was significantly greater for the two notification groups than the no notification group, off-task thoughts are the most likely cause of the observed between-groups performance differences.[7]

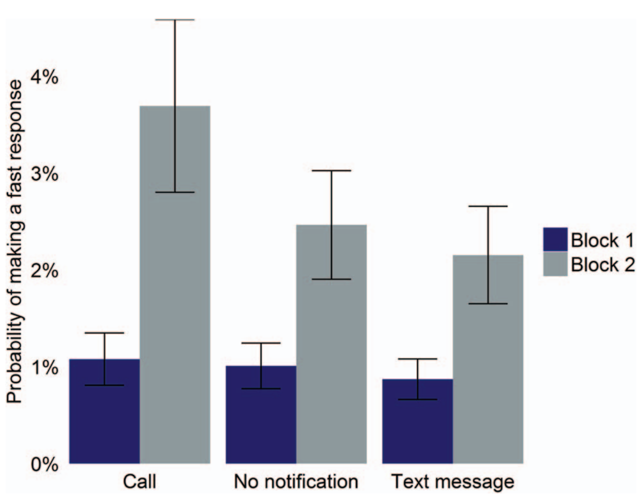

Figure 3. The probability of making a fast response (a response < 188.91 ms) by condition and block. Error bars represent 1 *SE*. See the online article for the color version of this figure.

Our study had several methodological advantages over other research on mobile phone−related distraction. First, both participants and experimenters were blind to condition and study hypothesis (see Boot, Blakely, & Simons, 2011; Rosenthal & Rosnow, 2009). However, in most distracted driving research, both participants and experimenters are aware of distraction condition, and the study hypothesis is easy to infer, especially given that distracted driving is often discussed in popular media. Although we do not dispute the validity of findings that performance on tasks is poorer when people are distracted, we recognize the possibility that participant and experimenter expectancies could exaggerate these effects. Our design rules this out as a potential explanation for our results. Second, our study used participants' own phones. We believe that our results likely depend on the fact that it was plausible that the calls and text messages received during the experiment contained personally relevant content. If participants had been aware that many of the notifications they received were part of the experiment, this would reduce, if not eliminate, the notifications' potential to prompt task-irrelevant thoughts.

There is a great deal of evidence that interacting with mobile devices, whether sending messages or engaging in conversations, can impair driving performance. Our results suggest that mobile phones can disrupt attention performance even if one does *not* interact with the device. We believe that this is an important consideration, particularly given the ubiquity of mobile phones in many people's day-to-day life. As mobile phones become integrated into more and more tasks, it may become increasingly

[6] We must, however, use some caution when interpreting the effects observed in the text message group. In terms of making a fast response, the block difference was equivalent between the text message group and no notification group. For commission errors, there was a greater block increase for the text message group than the no notification group, however, the baseline for the text message group was lower than the no notification group's baseline, and the second block difference between the two groups was equivalent. Taken together, these results make it difficult to determine whether the commission error difference between the text message group and no notification group is due to the text messages being distracting or something else (e.g., regression to the mean).

[7] It is possible that this relationship is mediated by anxiety and/or a temporary or long-term reallocation of attention.

difficult for people to set their phones aside and concentrate fully on the task at hand, whatever it may be. Further, it may be that the persistence of problematic mobile phone use is driven, at least in part, by the distracting effect of notifications. If people are genuinely distracted by notification-induced thoughts, some problematic mobile phone use could be prompted by the desire to escape that feeling of divided attention. Taken together, these findings highlight the need to adopt a broader view of cellular phone−related distraction.

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