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Nomophobia Impacts Physiological Arousal of Moderate and Heavy Smartphone Users Who are not Allowed to Access Text Messages during a Cognitive Task

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Abstract

This study examined physiological stress reactions—galvanic skin response (GSR) and heart rate—to an induced state of nomophobia (inability to use one's smartphone). A 2 x 2 experimental design was employed: half the participants received text message smartphone alerts that they could not answer; the other half silenced and put away their phones. Half the participants were heavy technology users and half were moderate technology users to examine stress reactions between groups that had previously displayed differing levels of self-reported anxiety. Those receiving unanswerable text messages demonstrated statistically higher GSR ranges immediately following alerts than the group who received no text messages. There were no differences in heart rate and no differences in GSR between heavy and moderate technology users. Not being able to access a text message induced strong measurable skin conductance spikes across both heavy and moderate technology users indicating that adult college students experience nomophobia physiologically.

Keywords: nomophobia, smartphones, galvanic skin response, text messages, physiological arousal

1. Introduction

Nomophobia is defined as "the fear of not being able to use one's smartphone and the services it offers" (Tams, Legoux, & Leger, 2018, p. 1). It has been described by King et al (2013; 2014) as the loss of access to information, the loss of connectedness and the loss of communication abilities and has been shown to negatively impact attention and learning (Mendoza, Pody, Lee, Kim & McDonough, 2018). Tams et al. (2018) reported a moderated mediation model that identified that the impact of nomophobia is strongest when the person is not in control of the smartphone and the situation. This study examines the loss of connectedness to text message communications as manifested through cognitive performance and physiological symptoms of anxiety when nomophobia is induced by moving one's smartphone out of range and sending text messages that the participant cannot view or answer.

Cheever, Rosen, Carrier, and Chavez (2014) removed smartphone device access (either turned off and stowed out of sight or exchanged for a claim check) from 163 college students and measured self-reported anxiety three times, 20 minutes apart starting 10 minutes after removing device access. While light smartphone users—scoring in the bottom tertile on a smartphone usage scale (Rosen, Whaling, Carrier, Cheever and Rokkum, 2013)—showed no change in anxiety across the study, heavy users showed continued increased anxiety across time. Moderate users who had their device taken away showed similar increased anxiety while moderate users who had a device close by and not accessible did not show increased anxiety. In addition, Rosen, Whaling, Rab, Carrier and Cheever (2013) found that college students were more anxious when not being able to check their text messages than not being able to check for phone calls, social media or work or personal email. Those who were most anxious about not being able to check text messages showed more signs of both mood disorders and anxiety-based disorders.

This study expands on past studies by examining the physiological responses of heart rate and skin conductance by both moderate and heavy smartphone users who received text messages that they were not able to access.

Anxiety associated with smartphone use has been studied in relation to not being able to check the device (Cheever, et al, 2014; Clayton, Leshner & Almond, 2015) and using the device too frequently or as a maladaptive tool (Elhai, Dvorak, Levine & Hall, 2017). Other studies have shown that Fear of Missing Out (FoMO) and anxiety were related to problematic smartphone use (Elhai et al., 2017), and a study of adolescents in the United States found that smartphone overuse was related to depression, anxiety and stress (Lister-Landman, Domoff & Dubow, 2017). Other studies have shown the mere presence of the device negatively impacts face-to-face communication (Przybylski & Weinstein, 2012); the quality of connectedness during conversations (Cheng & Yuan, 2014); and diminished attention and task performance (Thornton, Faires, Robbins & Rollins, 2014). A recent meta-analysis of 39 studies found small to medium associations between smartphone use and stress and anxiety (Vahedi & Saiphoo, 2018).

Newer studies have used physiological measures such as electrodermal activity to measure arousal while participants interact with a variety of technologies. Researchers out of Stanford University (Yeykelis, Cummings & Reeves, 2014) used skin conductance to measure arousal during task-switching from screen to screen on a computer. They found arousal began to rise, in general, 12 seconds prior to a screen switch and nearly 25 seconds prior to a switch from a "work" screen to an entertainment screen (i.e., video game, video or social media). In a recent unpublished study modeled after the famous "marshmallow effect" (Mischel & Ebbesen, 1970), Markowitz, Hancock, Bailenson, and Reeves (2018) required participants to be alone in a bare room doing nothing for six minutes while measuring electrodermal skin conductance under three conditions: (1) able to use their phone, (2) having their phone in another room and (3) having their phone available but told to "resist" using it (mimicking the marshmallow study condition). Results indicated that electrodermal activity was constant for three minutes across conditions at which point the group without their phone showed increased arousal. This validated the Clayton et al. (2015) study where participants completed word puzzles with or without their phone present. When the phone was in a different room participants showed decreased performance, and increased heart rate, blood pressure and self-reported anxiety compared to having the phone present.

Further, anxiety has been identified as a component of FoMO, which is defined as "the fears, worries, and anxieties people may have in relation to being in (or out of) touch with the events, experiences, and conversations happening across their extended social circles" (Przybylski, Murayama, DeHaan, & Gladwell, 2013, p. 1842), commonly associated with smartphone use. A study (Wolniewicz, Tiamiyu, Weeks & Elhai, 2018) found that FoMO was most strongly related to both problematic smartphone use and social smartphone use. Using the Smartphone Withdrawal Scale (SWS), another study found that restricting smartphone use was associated with the withdrawal symptoms of behavioral addictions including cravings, insomnia and depression/anxiety (Eide, Aarestad, Andreassen, Bilder, & Pallesen, 2018).

This study examines whether taking away moderate and heavy smartphone users' smartphones during a video-streamed 10-minute lecture and surreptitiously text messaging them causes changes in physiological arousal—measured by monitoring their skin conductance and heart rate—and negatively impacts memory for the lecture content. Further, participants heard incoming text message tones and vibrations (but were not able to view their device) during the key portions of the to-be-tested material to assess whether they kept their focus on the material or were distracted by their ringtones or alerts and the Fear of Missing Out on possible social communications.

Past experimental studies have examined the role of smartphone use on decreased task performance and anxiety levels. Rosen, Lim, Carrier and Cheever (2011) sent and received text messages to and from students viewing a video-streamed lecture. Students who received and sent the most text messages did significantly worse on the subsequent quiz about the lecture material than those who did not send or receive any text messages. Ward, Duke, Gneezy and Maarten (2017) had college students complete tasks that involved working memory capacity and fluid intelligence under three conditions: phone face down on the desk, phone stored in a pocket or bag, and phone placed in another room. When the phone was either on the desk or in a pocket or bag, working memory capacity was impaired; fluid intelligence was only negatively impacted by a face-down phone on the desk.

This study will enhance the understanding of how hearing a ringtone or alert on a smartphone and not being able to check it impacts task performance and arousal, as measured by heart rate and skin conductance. Although there is little research directly linking arousal with smartphone activity, we hypothesize, based on the Cheever et al. (2014) study, that heavy smartphone users will show stronger physiological arousal than moderate users. Further, studies on the impact of smartphone use on cognitive processing (e.g., Clayton et al., 2015) suggest that smartphone users should show decreased performance because of the distraction. Based on the literature, the following hypotheses are proposed:

2. Hypotheses

H1: A smartphone text alert will negatively impact cognitive performance in the text condition due to its distracting nature compared to a no text condition.

H2: A smartphone text alert will demonstrate increased physiological responses from GSR and heart rate for both heavy and moderate smartphone users in the text group compared to the no text group.

H3: A smartphone text alert to heavy smartphone users will show larger physiological responses for heavy smartphone users compared to moderate smartphone users in the text group.

3. Method

3.1 Participants

Participants were current students and recent graduates from a mid-sized Southern California university. Their ethnic makeup, gender, and ages reflect that of the campus and the community with 60% Latino/Hispanic, 15% Black/African American, 11% White/Caucasian, 6% Asian, 4% Hawaiian/Pacific Islander, 2% Native American and 2% other; 65% female and 45% male; and 55% ages 18-22 years, 41% ages 23-33, and 4% 34 and older. An earlier study on smartphone and other technology use was used as a screening device to obtain potential participants for the current study. That survey was distributed to more than 535 students in three campus courses and students were asked if they were interested in participating in a follow-up study. Overall, 192 students indicated interest in further studies and supplied contact information. Students who scored in the top two-thirds of the smartphone use subscale of the Media and Technology Use and Attitudes Scale (MTUAS; Rosen et al., 2013) were invited to participate in this study.

Recruiting efforts yielded 52 qualified and willing participants—26 moderate smartphone users and 26 heavy users—who were randomly assigned to one of two groups: those who had their smartphone taken away during the experiment and asked to leave their ringers and tones on (text) and those who kept their device with them and were asked to turn their ringers and tones off (no text). Four participants (two heavy smartphone users and two moderate users) were eliminated from the analyses because they either did not follow directions or because of experimenter error. Overall, 48 participants completed the study.

3.2 Research Design

A 2 x 2 between-subjects factorial design was used in this study. Both the moderate and heavy smartphone users were randomly assigned to one of the two following conditions: (1) removing and silencing their device (n=24, no text), or (2) keeping their non-silenced device a few feet behind them and out of sight (and surreptitiously texting the participants) but not allowing them to see the message (n=24, text).

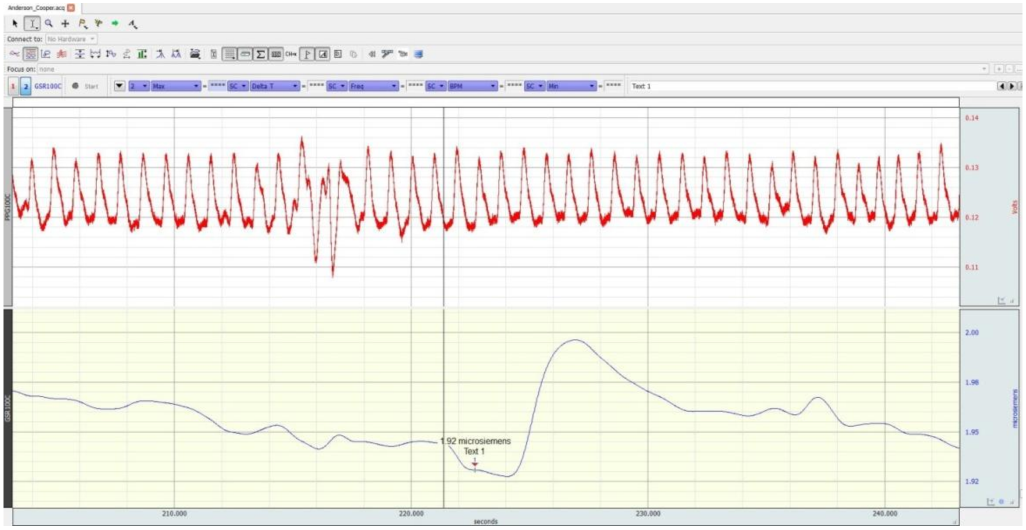
3.3 Procedure

Upon arrival at the test site, participants gave informed consent indicating they understood the purpose of the study, risk and/or benefits to them for participating, duration of the study (approximately 45-60 minutes), and what they would experience throughout the study, with the exception of the smartphone alerts. After voluntary consent was given, the experimenter seated the participant in front of the stimulus presentation computer and told the participant about the physiological measurement tools. The experimenter asked participants in the text group to temporarily give up their smartphones stating that they will interfere with the equipment if they are kept close by. To prevent participants in the experimental group from silencing or turning off their devices, we informed them that we wanted to simulate a naturalistic environment, as if they were doing the tasks at home. For the no-text group, experimenters asked participants to turn off their ringers and alerts and were allowed to keep their devices in their pockets or purses. For the text group, experimenters placed the smartphone device on a table several feet behind the participant, where they could be heard but not seen. Then, the experimenter applied both devices (described below) and took a one-minute baseline measurement of galvanic skin response (GSR) and heart rate. Participants were then told they would be viewing a lecture followed by a 10-item quiz. Participants were encouraged to do as well as possible on the quiz and those with the highest scores would be eligible for a $25 gift certificate. Participants were instructed to keep their head and hands still during the video lecture as any movement may alter the outcome of the physiological assessments. Then they began viewing a 10-minute video-streamed lecture. Four times during key points of the lecture, the experimenter texted a short message to the participant’s smartphone. Half the participants heard their smartphone’s alert (text) while the other half heard no smartphone alerts (no text). The text group received four text messages during the 10-minute period (Text1 at 1:25 minutes, Text2 at 2:05 minutes, Text3 at 4:20 and Text4 at 7:22). After the lecture was over, the participants took a 10-item quiz about the key points of the lecture. Four of the questions related to material they viewed while receiving the text message alerts but were unable to view or access the messages.

3.4 Measures

Physiological arousal measures: Two physiological devices were used to measure skin conductance (GSR) and heart rate simultaneously. These two devices measure psycho-physiological arousal, which is linked to an anxiety state. The skin conductance device is a non-invasive device used to measure galvanic skin response (GSR), which records changes in the electrical properties of the skin (i.e. electrodermal activity). Disposable, latex-free snap electrodes were pre-applied with isotonic gel (non-toxic; 0.5% chloride salt) and then adhered to the participants' index and middle fingers. Leads that are connected to the computer's receiver were then attached to the electrodes. The second device, which measures heart rate in real time, is an electrocardiogram (ECG) using similar properties as the GSR device aforementioned but measures cardiac activity. The device is a 3-Lead (3-channel) ECG and was worn on the participant's finger. The MP150 and EDA-100C receiver is a physiological data acquisition system that is tethered to the experimenter's computer station to record data in real-time using Acknowledge software. The data are then recorded through the RSPEC-R receiver coupled with the MP150 to measure data in real-time (see Figure 1). GSR is measured in microsiemens; heart rate is measured in beats per minute.

Figure 1. Output of physiological arousal measurements in response to an unanswered text message with heart rate (ECG) on the top frame and the galvanic skin response (GSR) on the bottom frame.



Task Performance Measure: A 10-minute video-streamed lecture about communication theory was shown to the participants. A 10-item quiz created on Survey Monkey about that lecture was administered on the screen directly after the participants viewed the lecture.

Deception or Incomplete Disclosure: Participants were not aware of the true nature of the study or why they were requested to remove the wireless mobile device from their possession. They were told they were participating in an experiment to measure how task performance (test-taking) impacts physiological arousal. After the study was completed, participants were given a debriefing statement explaining the true nature of the study.

4. Results

To examine whether participants from the text group experienced physiological arousal from hearing the incoming text message alert, we calculated the change in galvanic skin response (GSR) from three seconds prior to the alert being heard (latent state) to the highest peak (amplitude) of the reaction, which occurred within a range of four to eight seconds following the text message. For heart rate, we calculated the difference in beats per minute from three seconds before the texts to eight seconds after. For those in the no text group, we measured the GSR at the exact same period of time as if we had sent a text. The only difference was that we used a standard time frame of eight seconds to match the maximal period for the text group's GSR to demonstrate changes. For a change in GSR to be deemed an arousal event the threshold is a .05 increase between the latent state and the amplitude (Braithwaite, Watson, Jones, & Rowe, 2013). GSR "delta" scores—change from latent state—were calculated for each of the four text message events as well as averaged over those four events.

Heart rate increases were also recorded for the same time periods but no specific threshold criteria exist. Of the 96 text messages sent to each group, 61 arousal events (63%) were recorded in the text group, while 12 arousal events (13%) were recorded in the no text group.

4.1 Preliminary Analyses

First, two potential covariates, gender and age, were examined to determine if they were related to either of the dependent variables. Using a Pearson correlation coefficient, correlations between the potential covariates and the test score were calculated (two-tailed, $p < .05$) and indicated no significant correlations between test scores and gender or age. Second, comparisons were made to determine if the independent variables were related to either of the potential covariates. Neither age [$F(1,44) = 0.71$, $p > .05$] nor gender ($\chi^2 = 0.36$, $p > .05$) were related to the text-no text group nor were they related to the smartphone usage grouping—moderate vs. heavy—[[$F(1,44) = 0.02$, $p > .05$; $\chi^2 = 1.42$, $p > .05$, respectively]. Finally, the test score was examined in relation to the independent and arousal dependent data and found to be unrelated to all ($p > .05$).

4.2 Hypotheses Testing

Hypothesis 1 predicted that due to the interrupting nature of unanswerable text messages—timed to occur at the same time as the to-be-tested material on the video lecture—test performance should be worse in the text condition compared to the no text condition. A two-way Analysis of Variance indicated that the main effect of text vs. no text was not significant [$F(1,44) = 1.62$, $p > .05$] nor was its interaction with the smartphone usage condition significant [$F(1,44) = 1.03$, $p > .05$]. However, this may be because the test scores were rather high averaging 8.31 out of 10. Only two test items showed a score under 88%, the first (79%) and the last (46%). Perhaps the impact of unanswerable text messages was cumulative and impacted the final test question more than the prior three interrupted test questions. It is also possible that with a more difficult test and more unanswerable text messages we might have found an impact on learning. Further research is needed to test these assertions.

Hypotheses 2 and 3 investigated the impact of unanswerable text messages on physiological responses of GSR and heart rate between conditions and smartphone usage groups. First, a global two-way ANOVA was computed with text vs. no-text condition and heavy vs. moderate users as the independent variables and average GSR arousal score and heart rate arousal score as dependent variables. Those results are summarized in Table 1. As seen in Table 1, the only significant differences are for the text vs. no text main effect with a large ANOVA effect size for each significant main effect of text vs. no text based on Cohen's (1988) guidelines: low $\eta^2 =.01$, medium $\eta^2 = .06$, large $\eta^2 = .14$ (Fritz, Morris & Richler, 2012; Richardson, 2011). Averaged across all four text messages the text group ($M = .372$) showed a substantial GSR delta compared to the no text group who showed an expected lack of arousal ($M = .024$). This matches the data showing that 63% of the messages sent to the text group showed an arousal above the conservative criterion of .05 while only 13% of the no text group showed a similar arousal. Three of the four individual text messages also showed significant impacts on GSR (Text1: .371 vs. -.050; Text3: .390 vs. -.021; Text4: .401 vs. .089) and the fourth (the second text message) showed a similar, albeit nonsignificant (p = .063) trend (.325 vs. .079). In terms of our .05 GSR criterion, 58% of the participants in the text group had a recorded event during Text1, 63% during Text2, 63% during Text3, and 54% during Text4.

Table 1 also shows the comparisons between groups for heart rate and in every case, whether individual text messages or the average across them, there were no significant differences for condition or smartphone usage groups.

Table 1. Two-way ANOVA F-scores and effect sizes for physiological measure comparison by condition (text-no text) and smartphone usage (heavy-moderate)

Dependent Variables	Text vs. No Text (Condition)	Heavy vs. Moderate (Smartphone Usage)	Condition by Smartphone Usage
GSR-Mean	12.72*** ($\eta^2 =.224$)	0.05	0.15
GSR-Text 1	20.15*** ($\eta^2 =.314$)	0.32	0.33
GSR-Text 2	3.64	0.24	0.03
GSR-Text 3	14.15*** ($\eta^2 =.243$)	0.02	0.21
GSR-Text 4	4.15* ($\eta^2 =.086$)	0.01	1.19
Heart Rate- Mean	0.23	0.97	0.76
Heart Rate-Text 1	0.79	1.01	0.03
Heart Rate-Text 2	0.47	0.34	0.12
Heart Rate-Text 3	0.77	0.46	0.67
Heart Rate-Text 4	0.48	0.03	0.98

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

4.3 Additional Analyses

Additional text messages, beyond the ones sent by the experimenter, did arrive at the participants' phones including 25 for eight heavy smartphone users and 15 for nine moderate users averaging nearly 2.5 additional text messages during the 10-minute lecture or about one every four minutes. Overall, while the average GSR deltas did not differ significantly between heavy and moderate users' extra text messages, heavy users showed a more pronounced GSR spike (M = .281) compared to a smaller spike (M = .059) for moderate users [$t(15) = 1.19$, p = .121]. No differences in heart rates were found for the additional text messages.

5. Discussion

This study induced a feeling of nomophobia by removing smartphones from moderate and heavy smartphone users and then texting them while they were watching a recorded lecture and not allowed to access their phone to check their message. This study attempted to further Cheever, et al.'s (2014) research on smartphone dependency/problematic smartphone use and anxiety by measuring the physiological arousal of moderate and heavy smartphone users during a video lecture where they received four text message alerts but could not access their devices. Two physiological measures were used to test arousal: galvanic skin response (GSR) and heart rate. These two measures—when heightened—show an anxiety state, marked by the activation of the autonomic nervous system, which controls perspiration and heart rate. The main hypothesis for this study was that both moderate and heavy smartphone users who received the text messages would show significantly higher changes in their galvanic skin response (GSR) than those who did not receive the text messages. This hypothesis was confirmed. A two-way ANOVA of the mean changes in GSR revealed that the text message group demonstrated significantly higher GSR change than the no text group for all four text messages combined and for three of the four individual text messages. Participants also received additional text messages not sent by the experimenter (an average of one every four minutes of the 10-minute video-streamed lecture) and the means were strongly in the direction of an increased GSR again supporting the impact of nomophobia on participants' physiology. Unlike the strong GSR differences, there were no significant differences in heart rate between the two groups for either the sent or additional text messages. Although heart rate increases have been shown to be a function of arousal, they are highly variable and linked to motion and respiration (Choi & Gutierrez-Osuna, 2011; Lim & Kim, 2014). Given that participants may have moved in their seats while watching the video, it is not surprising that heart rate might not be a reliable measure of increased arousal.

We further hypothesized that there would be a difference in test scores between the two groups based on the texts being timed to enable an alert at the exact time test material was being discussed on the video lecture. We did not find any significant differences among quiz scores, suggesting that the distraction of the device's alerts did not hamper their attention to the lecture material. Although Rosen et al. (2013) found that forcing a student to respond to a text message under the same condition was detrimental to learning, forcing participants to ignore the alert did not have the same distracting power. However, the high mean test scores (83%) may indicate that the test was too easy and even a text distraction did not detract from learning the simple material. Interestingly, the material for the test item with the lowest score (46% correct) was presented during the video-streamed lecture at the same time the final text message was sent to the participants. Perhaps the distracting nature of unanswered text messages is cumulative and it takes some minutes for nomophobia to become a distraction.

The results of this experiment support Cheever et al.'s (2014) study in that they showed the absence of the smartphone was directly related to a higher anxiety-related state. However, unlike Cheever's study where moderate users who were sitting for an hour without a phone nor any work or conversation only showed anxiety when their phone was removed completely rather than stowed close by, there were no differences in skin conductance reactions between moderate and heavy smartphone users. This may suggest that nomophobia is particularly potent during a lecture rather than in a boredom-induced situation as in Cheever's study. The results suggest that receiving a text message alert and not being able to check the smartphone increases the GSR, or sweat, in people who are moderate and heavy smartphone users. Since GSR is directly related to people's anxiety levels through the activation of the autonomic nervous system which controls perspiration, the results further suggest that those receiving the text messages became more anxious during the experiment than those who did not receive text messages.

In conclusion, removing one's smartphone and then texting that person and not allowing him/her to access that message appears to produce a pronounced spike in galvanic skin response which is directly related to arousal, most likely negative arousal or anxiety in this situation. The effect was consistent and statistically large and suggested that nomophobia can have real consequences in an academic setting. The fact that moderate and heavy smartphone users showed the same effect points to the ubiquity of how an unanswered text message can induce anxiety.

Further experimentation could be done on other types of “alerts” and “notifications” including social media and news to further identify the source of the anxiety. If, for example, heightened GSR responses occur to social media alerts and not news alerts that may suggest that the cause of nomophobia is FoMO or fear of missing out on communications. Further research is also needed to determine the potential short- and long-term effects of stress and anxiety when immediate access to smartphones is not allowed such as in classrooms and other locations that ban smartphones (Dongre, Inamdar, & Gattani, 2017; Mendoza et al., 2018).

There are several limitations to this study. First, only moderate and heavy smartphone users were included. Perhaps a different effect would be found from light users who showed no increase in self-reported anxiety in the Cheever et al. (2014) study. Second, based on the high test scores it appears that the video lecture material may have been too simple to provide a mental distraction. Perhaps repeating the experiment in a classroom situation with a complex lecture would show unanswerable text messages negatively impact learning (Parry & le Roux, 2018; Waite, Lindberg, Ernst, Bowman, & Levine, 2018). Third, further research should explore the contribution of noises other than ringtones, beeps and alerts to people’s physiological arousal. It is possible that hearing any startling noise during times of concentration could increase people’s arousal levels.

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