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ABSTRACT

As smartphones increasingly pervade our daily lives, people are ever more interrupted by alerts and notifications. Using both correlational and experimental methods, we explored whether such interruptions might be causing inattention and hyperactivity—symptoms associated with Attention Deficit Hyperactivity Disorder (ADHD)—even in people not clinically diagnosed with ADHD. We recruited a sample of 221 participants from the general population. For one week, participants were assigned to maximize phone interruptions by keeping notification alerts on and their phones within their reach/sight. During another week, participants were assigned to minimize phone interruptions by keeping alerts off and their phones away. Participants reported higher levels of inattention and hyperactivity when alerts were on than when alerts were off. Higher levels of inattention in turn predicted lower productivity and psychological well-being. These findings highlight some of the costs of ubiquitous connectivity and suggest how people can reduce these costs simply by adjusting existing phone settings.

Author Keywords

Smartphones; interruptions; pervasive computing; multitasking; experimental study; attention management; subjective well-being; psychology

ACM Classification Keywords

H.1.2. [Information Systems]: User/Machine Systems—Human Factors; H.1.2. [Information Systems]: User/Machine Systems—Human Information Processing; H.5.2 [Information Systems]: User Interfaces—Auditory Feedback.

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INTRODUCTION

Ken is a married man, a father of four, and the founder and CEO of a digital ad agency. And he is struggling. In his early 40's, Ken noticed a significant decline in his ability to manage tasks, and gaps in his memory and performance. His desk had gotten increasingly cluttered, and when his employees started leaving the company frustrated by his inability to manage it, Ken decided to seek help. He wondered whether he might have an early-onset dementia or a thyroid dysfunction. What he did not expect is that his doctor would diagnose him with Attention Deficit Hyperactivity Disorder (ADHD). Ken wondered whether the recent exacerbation of his symptoms might be due to his increasingly stimulated digital environment.

The real story of Ken [43] is an example of how factors in our contemporary environment might exacerbate ADHD symptoms. Because ADHD is a neurodevelopmental disorder, however, a diagnosis cannot be based only on current symptoms, but also on a lifetime history of such symptoms. Ken's story, therefore does not suggest that digital distractions can cause ADHD. What his story does suggest, however, is that our increasingly pervasive digital technology may be causing inattention and hyperactivity—not only in people already suffering from ADHD, but also in the general population. In a recent survey, for example, one out of every two American smartphone owners reported having been distracted by their phones over the preceding week [31].

When Steve Jobs introduced the first smartphone in 2007, he promised: "This will change everything"; and he was right. Today, we can access the Internet virtually anytime and anywhere. And we do just that. The vast majority of smartphone owners use their phones not only for text messaging and calling, but also to check their email, keep up with their social media feeds, or simply to browse the Internet [31]. Of course, people could access these functions on their stationary computers even before they could carry these powerful computers in their pockets. What smartphones have changed, however, is where and when people access those functions. In a recent poll of smartphone users in the US, for example, almost all (95%) admitted to using their smartphones during their most recent social gathering, including to read incoming messages or emails or simply to check whether they had received any alerts [34]. In other polls, seven out of ten American smartphone owners were found to use their phones while working [31], and one in ten admitted to checking their phone even during sex [17]. According to some estimates people reach for their phones more than one hundred times a day [30] and spend close to two hours a day using their phones [12, 42].

Might the deluge of smartphone alerts and notifications be contributing to an increase in symptoms of ADHD in the general population? According to the Diagnostic and Statistical Manual (DSM-V)—the official guide for diagnosing mental disorders of the American Psychiatric Association—ADHD is characterized by two sets of symptoms: inattention and hyperactivity/impulsivity [4]. Inattention includes symptoms such as having difficulty focusing on one task at a time, being easily distracted, and getting easily bored when trying to focus. Hyperactivity is characterized by symptoms such as fidgeting, having trouble sitting still, and having difficulty doing quiet tasks and activities; in adults, hyperactivity also manifests as a sense of restlessness [22]. Smartphones may contribute to both sets of symptoms in the general population by serving as a readily available source of distraction (causing inattention) and of virtually unlimited array of alternative activities (causing hyperactivity). These effects could be exacerbated by the inflow of new notifications, which can both interrupt ongoing activities and present alternative activities [11; 14]. We propose, therefore, that the interruptions caused by smartphone notifications—from text messages and social media updates to emails and calendar reminders—could cause inattention and hyperactivity even in the general population.

Notifications, Interruptions, and Disruptions

A wealth of basic research and theory documents the toll of frequent task interruptions on attention and cognition. According to the time-based resource sharing model of attention [6], the very act of switching between tasks—even briefly—requires cognitive effort above and beyond the effort required to complete the tasks themselves. Switching attention thus increases cognitive load [6, 28]. And according to load theory of attention [24], the higher the cognitive load, the more susceptible people are to new distractors [36, 26]. To the extent that phone notifications draw users' attention away from other ongoing activities, phones may increase cognitive load. And by making people more prone to distractions, increased cognitive load may in turn make people—even in the general population—suffer from inattention and hyperactivity.

Beyond theory and basic research in cognitive psychology, a large body of work in HCI documents the detrimental effects of digital interruptions, particularly during tasks that require attention [3, 5, 10]. In field experiments, for example, digital interruptions at work (e.g., email alerts) have been associated with feeling more distracted, stressed, and anxious [23, 29]. And experiments in a controlled lab environment have revealed that notifications are disruptive in part because they interrupt people at random times. In one particularly well-designed lab experiment, participants completing common work tasks (e.g., editing text) felt more annoyed and frustrated, experienced greater time pressure, and expended more mental effort when they were interrupted by notifications at random than when uninterrupted [1]. In contrast, people suffered no consequences from being interrupted (i.e., no added frustration, time pressure, and mental effort) when they were interrupted at opportune times in between work tasks. Not all digital interruptions, then, are born equal: When people are interrupted by the random receipt of a new notification, they may be particularly likely to incur attentional and emotional costs.

An emerging body of literature shows that people often attend immediately to notifications received on their phones [8, 32, 37]. This suggests that phone notifications often interrupt other activities at random times, making phones particularly disruptive [1]. Phones' power to interrupt their users is no doubt in part due to their omnipresence throughout our daily activities. Indeed, people attend to new notifications quickly regardless of the alert mode on their phones (e.g., ring vs. vibrate vs. silent) [8, 32]. Still, people are more likely to attend immediately to, for example, new text messages when their phones are in vibrate or ring mode than when they are in silent mode [8]. Above and beyond phones' omnipresence in our lives, then, the rings, dings, and vibrations accompanying new notifications may levy users' attention further by interrupting other tasks at random times. In fact, the very sound of a new alert has been shown to disrupt ongoing tasks. In a recent study, the mere buzz of a new notification was enough to hurt performance on a cognitively demanding task even when people did not attend to the notification (e.g., checked the text message announced by the notification) [41]. Yet, people typically keep their phone alerts on—about 9 in 10 notifications are received in ring and vibrate modes [32]. To the extent that people normally attend immediately to phone notifications and random interruptions tax attention, phone notifications may cause even people not diagnosed with ADHD to suffer from inattention and hyperactivity.

Study Overview

We recruited a sample of university students from the general student population. During an initial study session, we assessed individual differences between participants in inattention and hyperactivity while also measuring how frequently people felt interrupted by their phone notifications. We thus explored correlationally whether feeling interrupted by phone notifications was associated with inattention and hyperactivity. Because ADHD symptoms have been associated with poorer performance at work/school and with relationship and social skills problems [13, 15, 22], we also included exploratory measures of productivity and psychological well-being.

While correlational analyses provide the most naturalistic way to examine the association of phone interruptions with inattention and hyperactivity, such analyses preclude causal conclusions. Accordingly, we ran a two-week within-subjects experiment in which we manipulated how frequently participants felt interrupted by their smartphones. For one week, we assigned participants to maximize phone interruptions by keeping notification alerts on and their phones within their sight and/or reach. During another week, we assigned the same participants to minimize phone interruptions by keeping alerts off and their phones away. By employing this within-subjects design, we were able to examine whether phone interruptions had causal effects on inattention and hyperactivity.

METHOD

Participants

Two-hundred and twenty-one undergraduate students (M_{age} = 19.89; 73.76% female) from the University of British Columbia completed the study in exchange for course credit. Importantly, students were recruited from the university's general participant pool, rather than from a pool of students diagnosed with ADHD. We calculated our sample size based on *a priori* analyses with 80% probability of detecting small effects of d = .20, α = .05, two-tailed[1]. Because we were interested in manipulating how frequently people felt interrupted by their smartphones, we prescreened participants for smartphone ownership; all participants thus had a smartphone[2].

Procedure

Participants attended an introductory session in the lab in groups of up to 10 students. Before assigning them to experimental condition, we assessed our main measures of interest at baseline, including phone interruptions, inattention and hyperactivity, as well as productivity and psychological well-being (see Measures). Participants were then assigned to condition using a randomized counterbalanced within-subjects design. Half the participants were assigned to minimize interruptions for one week and then to maximize interruptions for a second week. For the other half of the participants, the order of these instructions was reversed.

In the *Do-Not-Interrupt* condition, participants configured their smartphones to Do-Not-Disturb settings, disabling auditory (e.g., ring), tactile (i.e., vibration) and visual alerts (i.e., LED flashes). In order to prevent participants from compensating by monitoring incoming notifications on their screens, we additionally asked them to keep their phones out of sight (e.g., in their bags, pockets).

In the *Interrupt* condition, participants configured their phones to enable auditory, tactile, and/or visual alerts. Additionally, participants kept their phones within their sight and/or reach. In situations where their phones may be disruptive to others (e.g., in class), participants in this condition were instructed to use common sense and to switch off audible alerts if necessary. Even in such situations, however, participants were instructed to have their phones at least on vibrate mode.

All participants within a single introductory session were assigned to the same condition. All participants were guided through how to configure their phones in silent, ring, and vibrate settings. Additionally, each participant was given a sheet detailing how to configure his or her phone to the assigned settings; the sheet contained information about the most common smartphones and operating systems (e.g., iPhone, Android).

After the introductory session, participants were sent daily online surveys in the evening on each of the next six days. During the first day of the second week, participants were sent a prompt via email to change their phone settings as shown on their instructions sheets. Then, for each of the following six days, participants again received links to complete daily surveys. In the first five surveys of each week, we assessed how frequently people felt interrupted by their phones during a specified one-hour period of the day. This measure served as our manipulation check (see Measures)[3]. On the seventh and last day of each week, participants received a longer survey asking them to report how they felt over the past week. This survey contained our main variables of interest, including inattention and hyperactivity, productivity, and psychological well-being. At the end of the two weeks, participants returned to the lab to be debriefed in person.

Measures

Smartphone Interruptions

At baseline, we assessed how frequently participants normally felt interrupted by their phones (from 0—*not at all* to 6—*constantly*) when engaging in 14 common daily activities (e.g., attending class, reading for pleasure, commuting, or eating[4]). Interruptions were defined as any time participants' attention shifted from their current

[1] The power analyses were registered on Open Science Framework: http://tinyurl.com/ofx3jjy.

[2] Because we did not want people to get around our manipulation of smartphone interruptions by using other portable devices, we also prescreened people for how much they used tablets. People who reported using a tablet often or all the time in prescreening were not eligible to participate.

[3] These daily questionnaires included other questions beyond the main scope of the present investigation of the effects of phone interruptions on inattention and hyperactivity. The full questionnaire is available here: http://tinyurl.com/nfsux27.

[4] The full version of the baseline survey, including a list of all activities is available here: http://tinyurl.com/nfsux27

activities to their phones because of a notification. We asked people to report interruptions separately for these 14 activities in order to cue people to think about their behavior during specific activities, making their estimates more accurate. We averaged people's responses across all 14 activities to form a single measure of phone interruptions at baseline.

In order to assess the successfulness of the manipulation, we also asked people to report daily how frequently they felt interrupted by their phones (0–*not at all*; 6–*constantly*). We used a self-report measure of interruptions because no available technology can objectively assess how frequently people feel interrupted by their phones. Indeed, people's subjective sense of being interrupted should depend not only on how quickly people attend to notifications but also on what they are currently doing (e.g., trying to pay attention in class versus mindlessly commuting). Still, we used past research to design our self-report measure to be as accurate as possible. Specifically, people have been shown to provide more accurate information about their behavior when asked what they were doing during specific periods of time in the day [e.g., 21]. Accordingly, participants were first prompted to remember what they were doing during a one-hour period of time on each day, and then to report how frequently they felt interrupted by their phones during this period. The specific time period participants were asked about varied by day. To represent the range of activities people engage in during different times of the day, we first selected every other possible one-hour period, starting at 10 am and ending at 7 pm (i.e., 10 am to 11 am, 12 pm to 1 pm, and so forth). We then randomly assigned one of these time periods for each day of the week.

Inattention and Hyperactivity

To measure inattention and hyperactivity (both at baseline and at the end of each week of the study), participants rated the extent to which they experienced 18 symptoms over the past week (1–*never*; 2–*rarely*; 3–*sometimes*; 4–*often*). These 18 items were based on the criteria of the Diagnostic and Statistical Manual – V (DSM-V) for diagnosing ADHD [4, 16]. Nine items assessed inattention (e.g., *How often were you easily distracted by external stimuli, like something in your environment or unrelated thoughts?*); the other nine items assessed hyperactivity (e.g., *How often did you have difficulty waiting your turn, such as while waiting in line?*). We averaged each set of nine items to form our measures of inattention (α = .82) and hyperactivity (α = .79[5]) at baseline and for each of the two experimental weeks.

Productivity

We measured participants' productivity at baseline and at the end of each week of the study with three self-report items used in previous research [23]. We asked participants the extent to which in the previous week they: (1) felt that they got the things done at work or school that were important to them; (2) were satisfied with what they had accomplished at school; and (3) felt a sense of accomplishment from school (α = .88).

Psychological Well-Being

To measure well-being broadly, we assessed several constructs theorized as essential components of psychological well-being. In particular, Ryff [36] has argued for six components of psychological well-being, including a sense of autonomy, environmental mastery, self-acceptance, personal growth, purpose and meaning, and relatedness with others. To reduce the burden on participants from completing measures of all these aspects of psychological well-being, we assessed only four. Specifically, we did not assess people's sense of personal growth and self-acceptance because we deemed it unlikely that these aspects of psychological well-being would be related to inattention and hyperactivity. In contrast, based on past research [13, 15, 22], we theorized that inattention and hyperactivity might have downstream consequences for people's sense of mastery over their environment, autonomy over their actions, relatedness to others, as well as how meaningful they found their daily lives.

To measure participants' environmental mastery, we used the short version of the environmental mastery questionnaire [35], which includes three items (α = .73). To assess mastery during each specific week of the study, we adapted the items so that people reported their sense of mastery over the past week. Participants provided their responses using a scale from 1–*strongly disagree* to 7–*strongly agree.*

Although Ryff [36] has developed scales for all aspects of psychological well-being, Ryff's scales of the other aspects were not adaptable for measuring the constructs over a one-week period (rather than in their life in general). Accordingly, we adapted measures from other commonly used scales to assess the other aspects of psychological well-being. To measure participants' sense of relatedness with others, we adapted 5 items from Social Connectedness Scale [27]. Participants reported, for example, how distant they felt from others and how disconnected they felt from the world around them (both reversed scored). Participants used a scale from, 1–*strongly disagree* to 7–*strongly agree.* This adapted scale demonstrated high reliability (α = .94).

To measure participants' sense of autonomy, we adapted five items from the Perceived Choice Scale [38, 39] (α = .85). For each item, participants were given two statements (A and B) and asked to respond on a scale from 1–*only A feels true* to 5–*only B feels true*. For example, participants were asked to decide between *A—I felt like I always chose the things I did* and *B—I sometimes felt that I was not really choosing the things I did.*

[5] All alphas are reported as averages of the alphas of the three measures of each construct (i.e., baseline, week 1, and week 2)

	Interruptions	Inattention	Hyperactivity	Productivity	Environmental Mastery	Social Connectedness	Perceived Choice	Meaning in Life	Life Satisfaction
Interruptions	–								
Inattention	.31***	–							
Hyperactivity	.30***	.41***	–						
Productivity	−.14*	−.41***	−.09	–					
Environmental Mastery	−.18**	−.52***	−.27***	.34***	–				
Social Connectedness	.01	−.26***	−.27***	0.13*	.29***	–			
Perceived Choice	−.09	−.36***	−.13†	.25***	.35***	.24***	–		
Meaning in Life	−.11†	−.28***	−.11	.36***	.49***	.35***	.38***	–	
Life Satisfaction	−.05	−.41***	−.15*	.42***	.64***	.46***	.39***	.50***	–

Table 1: Table of correlations between baseline measures. *** p < .001; ** p < .01; * p < .05; † = p < .10

To measure participants' meaning in life, we used five items of the Meaning In Life Questionnaire—Presence Subscale [40] (α = .89). Participants reported their agreement with each item on a scale from 1–*strongly disagree* to 7–*strongly agree.*

At baseline, we additionally included a broader measure of life satisfaction in general: *Taking all things together, how satisfied are you with your life these days?* (0–*not at all satisfied*; 6–*very satisfied*) [7].

RESULTS

Are smartphone interruptions associated with inattention and hyperactivity? To explore this question, we first ran a series of correlational analyses using people's self-reports at baseline. We then examined this question causally by comparing whether people reported higher levels of inattention and hyperactivity when they were randomly assigned to maximize (versus minimize) interruptions.

Correlational Analyses at Baseline

As seen in Table 1, people who reported more phone interruptions at baseline also reported higher levels of both inattention (r = .31, p < .001) and hyperactivity (r = .30, p < .001). Consistent with past research, we also found that inattention and hyperactivity were negatively associated with our measures of self-reported productivity and psychological well-being (see Table 1). Notably, inattention was more strongly associated with these outcomes than was hyperactivity. In addition, people who reported feeling interrupted by their phones more frequently felt less productive, experienced a lower sense of environmental mastery, and also reported marginally lower sense of meaning in life.

To explore whether inattention and hyperactivity mediate the relationship between smartphone interruptions and our measures of productivity and psychological well-being, we ran a series of mediational analyses using both bootstrapping with 50,000 replications [18] and Sobel's test of mediation. Inattention mediated the effect of interruptions on productivity, *indirect effect* = −.15, 95% CI [−.23; −.08], *Sobel's Z* = −3.78, p < .001, leaving a nonsignificant direct effect of interruptions on productivity, b = −.02, 95% CI [−.17; .12]. Inattention also mediated the effect of interruptions on environmental mastery, *indirect effect* = −.17, 95% CI [−.26; −.09], *Sobel's Z* = −4.18, p < .001, leaving a nonsignificant direct effect, b = −.02, 95% CI [−.15; .11]. Finally, inattention explained the effect of interruptions on meaning in life, *indirect effect* = −.11, 95% CI [−.19; −.05], *Sobel's Z* = −3.02, p < .01, leaving a nonsignificant direct effect, b = −.04, 95% CI [−.21; .14]. In short, inattention explained the negative associations between phone interruptions and our measures of productivity and psychological well-being.

In contrast to the strong mediating role of inattention, hyperactivity played a less important role in explaining the negative associations of phone interruptions with productivity and psychological well-being. Specifically, hyperactivity did not mediate the association of phone interruptions to productivity, *indirect effect* = −.02, 95% CI [−.07; .03], *Sobel's Z* = .71, p = .48 or meaning in life, *indirect effect* = −.03, 95% CI [−.10; .02], *Sobel's Z* = −1.15, p = .25. And although hyperactivity mediated the effect of interruptions on environmental mastery, *indirect effect* = −.08, 95% CI [−.15; −.03], *Sobel's Z* = −2.79, p < .01, this indirect effect was weaker than the indirect effect of inattention.

The above mediational analyses are correlational; it is, therefore, possible that inattention may make people more susceptible to feeling interrupted by their phones (rather than that phone interruptions cause inattention). If this alternative direction of causality describes the data, phone interruptions should mediate the negative associations of inattention with productivity and psychological well-being. In contrast to this possibility, phone interruptions did not mediate the associations of inattention (*b*'s = −.01 to −.02, *p*'s > .68) with our measures of productivity and psychological well-being. Thus, our correlational analyses at baseline are most consistent with a single causal path: Phone interruptions impair productivity and psychological well-being to the extent that interruptions increase inattention.

Experimental Results

To directly explore whether phone interruptions can cause inattention and hyperactivity[6], we next present the effects of our experimental manipulation.

Manipulation Check

Confirming the success of our manipulation, we found that people felt more frequently interrupted in the *Interrupt* condition (M = 2.64, SD = 1.04) than in the *Do-Not-Interrupt* condition (M = 2.03, SD = .92), $t(210)$ = 8.06, p < .001. Interestingly, people felt less interrupted by their phones in the *Do-Not-Interrupt* condition than normal, as assessed at baseline (M = 2.75, SD = 96), $t(210)$ = 10.20, p < .001; in contrast, people felt no more interrupted in the *interrupt* condition than at baseline, $t(210)$ = 1.56, p = .119.

Main Effects

Did maximizing phone interruptions for a week result in reporting higher levels of inattention and hyperactivity? A paired-samples t-test comparing inattention symptoms between each of the two weeks revealed that participants indeed experienced higher levels of inattention in the *Interrupt* condition (M = 2.38, SD = .58) than in the *Do-Not-Interrupt* condition (M = 2.27, SD = .56), $t(189)$ = 3.02, p = .003, d = .44. Mirroring this effect on inattention, people also reported higher levels of hyperactivity in the *Interrupt* condition (M = 2.11, SD = .59) than in the *Do-Not-Interrupt* condition (M = 2.01, SD = .55), $t(189)$ = 3.12, p = .002, d = .45. Notably, both effects were of medium size according to established statistical guidelines in the behavioral sciences [8].

We found no significant main effects of our manipulation on our measures of productivity and psychological well-being, *t*'s < .89, *p*'s > .37. It is, of course, hardly surprising that our minimal manipulation did not produce significant differences in these outcomes within the frame of one week. Still, our correlational findings showed that phone interruptions were negatively associated with productivity and psychological well-being, as well as that these negative associations were explained by inattention. Accordingly, we next examined whether our manipulation of phone interruptions had downstream consequences for productivity and well-being to the extent people suffered greater inattention when maximizing (vs. minimizing) interruptions.

Indirect Effects

To explore the indirect effects of our manipulation on productivity and psychological well-being through inattention, we followed recommendations by Judd and colleagues [20] for conducting mediation analyses with repeated measures. As shown in Eq. (1) below, in each case we predicted the difference scores in the outcome variables (Y) from the sum and difference scores of inattention (X). The regression coefficient of the difference scores of inattention (controlling for its sum scores) is the measure of the indirect effects of the manipulation on productivity and well-being through inattention [20]. As shown in Figure 1, to the extent that people experienced greater inattention in the *Interrupt* (vs. *Do-Not-Interrupt)* condition, they felt less productive and less socially connected, reported less mastery over their environment and lower meaning in life, and perceived less choice over their actions.

$Y_{\text{diff}} = b_1 X_{\text{sum}} + b_2 X_{\text{diff}} + \varepsilon$, where

(a) $Y_{\text{diff}} = Y_{do\text{-}not\text{-}interrupt} - Y_{interrupt}$

(b) $X_{\text{diff}} = X_{do\text{-}not\text{-}interrupt} - X_{interrupt}$

(c) $X_{\text{sum}} = X_{do\text{-}not\text{-}interrupt} + X_{interrupt}$

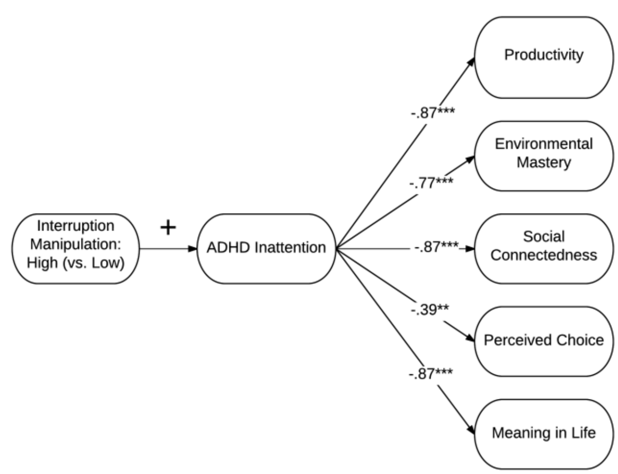

Figure 1. Indirect effects of manipulating smartphone interruptions on psychological well-being via inattention symptoms. Numbers are unstandardized regression coefficients.

[6] Note that degrees of freedom vary slightly between tests due to failure by some participants to complete some measures.

DISCUSSION

We provide the first evidence that interruptions due to phone notifications can cause inattention and hyperactivity in the general population. When people maximized phone interruptions by switching alerts on and keeping their phones within reach, they felt higher levels of inattention and hyperactivity than when they minimized phone interruptions. In line with these experimental findings, correlational analyses at baseline also indicated that people who felt interrupted by their phones more frequently experienced higher levels of inattention and hyperactivity. In both the correlational and experimental analyses, the effects of phone interruptions on inattention had downstream consequences for self-reported productivity and psychological well-being. By triangulating on correlational and experimental methods, therefore, we demonstrated that phone interruptions might cause symptoms of ADHD in the general population. Our findings also suggest, however, that people could mitigate these negative effects by making simple modifications to the notification settings of their phones.

Despite our promising findings, we caution that keeping notifications at bay may not work equally well for everybody trying to reduce phone interruptions. Preliminary qualitative research suggests that for some, disabling alerts may produce anxiety over missing notifications [33]. Such anxiety may drive some to self-interrupt more, resulting in a net increase in interruptions. In one study, for example, information workers disabled their email notifications for one week; while some workers were able to reduce their email checking compared to baseline, others checked their email more to avoid missing important messages [19]. Future research should, therefore, examine what personality characteristics (e.g., neuroticism) and what situational factors (e.g., job type, duration of intervention) determine when and for whom switching off notifications leads to net benefits.

To manipulate phone interruptions in the present research, we asked people to switch alerts on versus off, as well as to keep their phones within sight versus out of sight. Assuming that the old adage—out of sight, out of mind—holds true, our manipulation may have influenced not only external interruptions but also self-interruptions. While past research suggests that the unpredictable timing of external notifications may be especially disruptive to users [1], future research should examine whether self-interruptions contribute to inattention and hyperactivity above and beyond external interruptions. Indeed, even when using silent mode, people normally attend to new phone notifications within 6 minutes [8], suggesting that self-interruptions may account for a large proportion of the interruptions in people's daily activities [cf. 11].

For the purposes of the present research, we used self-report measures to detect differences in how frequently people felt interrupted by their phones. Because people have been shown to underestimate the frequency of their smartphone use [42], the particular values reported by participants should be interpreted with caution. We note, however, that self-report measures were better suited for the purposes of the present investigation than available objective measures. Indeed, past research using objective measures has captured only how quickly people attend to incoming notifications, rather than whether people feel interrupted by these notifications given their current context and activities [8; 32]. Using these objective measures, researchers have shown only small—but statistically significant—differences between how quickly people attend to new notifications in silent versus ring/vibrate modes [8]. By relying on a subjective measure, the present research suggests that even such minor differences in attentiveness to new notifications may make users feel more interrupted by their phones.

By using a subjective measure of phone interruptions, we were able to hone in specifically on how frequently people's attention was drawn to their phone due to a notification. But our measure thus captured only external rather than self-initiated interruptions. In contrast, objective measures in past research have captured both external and self-interruptions (i.e., any time a person attends to a notification [8; 32]). It is possible, therefore, that a subjective measure assessing both external and self-initiated interruptions may have produced a smaller difference between conditions—similar to the available objective measures. Even such a subjective measure, however, would not be conceptually equivalent to the available objective measures. Such measures can accurately assess how frequently users attend to notifications; but they cannot adequately capture how frequently users are interrupted because these measures ignore people's current goals and activities. Attending to a notification may be interruptive when a person is in a meeting or class, but not when she is on the bus or bored at home. The present research thus suggests that subjective measures of interruptions are not simply coarser, less precise versions of the available objective measures; rather, subjective measures can be useful additional tools for studying the psychological effects of our ubiquitous digital devices. We invite future research to use both subjective and objective measures in order to disentangle how the feeling of being interrupted by notifications relates to the objective frequency of attending to notifications.

In order to conduct the first systematic investigation of the effects of phone interruptions, we included a wide range of outcome measures, which included inattention and hyperactivity, but also many other constructs. Given this exploratory approach, it is possible that the significant effects we observed are simply an artifact of the large number of statistical tests we conducted. Importantly, however, we found consistent effects on inattention and hyperactivity both in our correlational analyses at baseline and in our two-week field experiment. This converging evidence of our correlational and experimental analyses make less likely the possibility that our findings are a mere statistical fluke. Still, the present study should be seen as laying the groundwork for further confirmatory research.

Inherent in our within-subjects design lies another limitation of the present study: Participants were aware of the two conditions within our manipulation. To the extent that people might have theories about how their phones affect them, people may have reported how they thought they should feel rather than how they actually felt. But we found the same associations of phone interruptions with inattention and hyperactivity using our baseline measures, which were administered before condition assignment. Viewed in the context of our correlational findings, therefore, our experimental findings are unlikely to be completely explained by participants' lay theories.

We found no direct effects of our manipulation on our measures of productivity and psychological well-being. It is, of course, hardly surprising that keeping notifications at bay for a week did not produce direct effects on, for example**,** how meaningful people found their lives. Still, to the extent that phone interruptions influenced inattention, they had downstream consequences for productivity and well-being. Future research should explore whether these indirect effects may materialize into direct effects if people minimize phone interruptions over periods of time longer than a week (e.g., one month, an entire semester).

We found that smartphone interruptions were associated with self-reported symptoms of ADHD in a sample drawn from the general population. But our findings do not in any way suggest that smartphone notifications can cause ADHD, which is a neurodevelopmental disorder with complex neurological and early developmental causes [4]. But as with any other disorder, symptoms represent a continuum from the normal to the pathological. Our findings thus simply show that smartphone interruptions may be driving individuals from the general population to feel somewhat more inattentive and hyperactive. The present research can thus be seen only as an initial demonstration of the potential role of smartphones in exacerbating symptoms associated with ADHD.

Just as we do not suggest that phone interruptions can cause ADHD, we by no means claim that reducing phone interruptions can treat ADHD. Indeed, our findings are based on a sample drawn from the general student population, rather than from a population diagnosed with ADHD. What our findings do suggest is that being constantly interrupted by alerts and notifications may be contributing towards an increasingly problematic deficit of attention in our digitally connected society. In an age of incessant digital stimulation, we hope that our findings would spur further research on how people can reclaim control over their attention.

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