Lifting the veil on smartphone screen time:

The role of notifications and specific app activities in explaining session length

Abstract

While research on the association between screen time and health and wellbeing is flourishing, scholars warn for a lack of conceptual and empirical clarity on what screen time entails. This is problematic, because a lack of understanding about what screen time entails prevents us from understanding when screen time becomes excessive and/or problematic. This study presents an exploratory attempt to clarify the nature of screen time. To that end, it quantifies the role that notifications and app activities, in particular social media and communication app activities, play in explaining smartphone session duration. Drawing from the smartphone log data of 125 individuals, a generalized linear mixed modeling analysis indicates that smartphone sessions starting with a notification are on average 22% shorter. The use of one or more social media apps, on the other hand, increases session length on average by 8%. No such effects were found for communication apps. These findings support a theoretical and methodological differentiation between communication and social media apps in research focusing on screen time and its association with health and wellbeing.

Introduction

Smartphone overuse and the association between smartphone use and various indicators of health and wellbeing receive ample attention in both the public and the scholarly domain. This is not surprising given the amount of time that individuals spend on their phones. Sewall et al. (2020), for instance, report a daily median smartphone use of 3.18 hours.

While there is a wealth of research finding links between smartphone use and various psychological conditions and physical ailments, scholars have recently voiced concerns over the validity of this research, raising critical questions about the conceptualization and operationalization of screen time (Orben & Przybylski, 2019; Kaye et al., 2020), and the inaccuracy of screen time self-reports (Sewall et al., 2020). Because these issues may lead to biased interpretations of findings, there is a general call in the field to rely more heavily on behavioral measures of screen time, for instance in the form of smartphone log data (Hendrickson et al., 2019). In addition, there is a call for greater conceptual clarity on what screen time is, and how 'problematic' forms of screen time should be operationalized (Whitlock & Masur, 2019). In discussions over screen time and its association with health and wellbeing, for instance, the distinction between passive versus active social media usage, and how to measure it, remains debated (Beyens et al., 2020).

Given the concerns in the field over screen time and how to best conceptualize and operationalize its nature, it is surprising that few studies have actually teased apart the nature of smartphone screen time. Such an inquiry is relevant. To date, for instance, studies still rely on generic measures of smartphone use duration to draw empirical observations on the role that smartphones play in eliciting serious mental health conditions such as depression and suicidal ideation (Twenge, 2018). But which smartphone activities typically drive smartphone duration? This knowledge is relevant in broader discussions over smartphone use, as a better understanding of what smartphone use entails can give further credence to the assumed mechanisms explaining its effects.

Survey research indicates that social networks and communication applications are generally considered to generate significant proportions of smartphone use (e.g., Sha, Sariyska, Riedl, Lachmann, & Montag, 2019). Furthermore, push notifications, particularly notifications generated by social networks sites, appear a major driver of (excessive) smartphone use. Push notifications, "…a visual cue, auditory signal or haptic alert, generated by an application or service that relays information to a user outside her current focus of attention" (Pham, Nguyen, Hwang, & Chen, 2016), are a ubiquitous element of mobile devices. They are one of the primary tools that online and mobile platforms use to draw attention to their digital products. Attended to by most smartphone users within minutes, notifications are a pervasive and intrusive element of mobile devices. Their effects on smartphone users are complicated. While primarily designed as a tool to create informational awareness, they have developed into a major source of attention disruption (Iqbal & Horvitz, 2010). Research shows an increase of the duration and frequency of smartphone use with an increase of notifications (Kim et al., 2016).

Notifications are often primarily associated with communication and social media apps, where they signal to the user that there has been interaction with their content or their account. As such they may trigger users to quickly screen their communication or social media apps for this interaction. They may, however, also form a gateway to users to engage in more prolonged activities on their smartphone.

But notifications are not restricted to these apps: Stroud, Peacock & Curry (2020) for example, report that breaking news alert on locked screens increase self-reported use of news applications. Ample research reports on the negative effects of compulsive smartphone checking behavior, induced by notifications, for example on academic grades (Johannes, Veling, Verwijmeren, & Buijzen, 2019; Wilmer, Sherman, & Chein, 2017) or psychological outcomes including anxiety and depression (Elhai, Rozgonjuk, Alghraibeh, & Yang, 2019). On a more positive note, push notifications are considered to be effective at increasing engagement in mobile learning platforms (Pham et al., 2016) or digital behavior change interventions (Alkhaldi et al., 2016).

The studies mentioned above indicate the role of social media apps, communication apps and notifications in smartphone use. To our knowledge, no studies have attempted to quantify their role in smartphone session duration. Therefore, the objective of this paper is to quantify the effect of (1) notifications which trigger unlocking of the smartphone; (2) additional notifications during the session and (3) the presence of social media and communication apps, on smartphone session duration.

Method

Data collection

Smartphone log data were collected with the MobileDNA app, an Android-based application, built at Ghent University for research purposes. We invited 2.754 individuals to voluntarily install the mobileDNA app on their smartphone and to anonymously share their data with the researchers. 236 individuals eventually installed the app. Among these individuals, 87.641 smartphone sessions, collected from October 7th, 2019 until October 20th, 2019 were collected. Per session, a session identifier, participant identifier, start and end time of each app event (the launch of an app during the session) and whether or not the app event was preceded by a notification were collected. Data cleaning involved selecting those participants who logged the full 14 days and removal of sessions shorter than 1 second and longer than the mean session length + 3 standard deviations. 73.250 smartphone sessions, from N=125 individuals, were retained for analysis.

Participants

Table 1 presents the sociodemographic characteristics of the participants. The sample has an overrepresentation of male participants. Age is also not normally distributed ($W(125)= 0.9269$, $p < 0.001$), with 56% of participants aged between 20 and 40 years.

Table 1. Participant demographics

	Sample (N=125)
Age	
Mean (SD)	39.1 (15.6)
Median [Min, Max]	34.0 [18.0, 83.0]
Gender	
Male	81 (64.8%)
Female	44 (35.2%)

Measures

From the smartphone log data, the following measures were calculated. The dependent variable in the study is smartphone *session length***,** which was calculated as the time difference between the start time of the first app event and the end time of the last app event under a session identifier. The independent variables can be divided into (1) variables pertaining to a single smartphone session (*whether or not the session started with a notification, the number of app events ('app event count') per session, the number of notifications ('notification count') per session, the presence of social media apps in session*[1]*, and the presence of communication apps in session*[2]), (2) aggregate measures of a participant's smartphone sessions (*average session length per participant, total session count per participant*) and (3) socio-demographic characteristics of the participants (*age* and *gender*).

Analyses

Due to the multilevel structure of the data (multiple smartphone sessions nested within participants), and an approximated gamma distribution of the dependent variable, Generalized Linear Mixed Modeling (Gamma family with a log link, ML estimation and BOBYQA optimizer) was used to model smartphone sessions length. R package 'LME4' (Bates, Mächler,

[1] Social media apps category contains Instagram, Facebook, Twitter, LinkedIN
[2] Communication apps category contains phone calls, WhatsApp, Snapchat, Facebook Messenger, other messaging apps (MMS, SMS), email

Bolker, & Walker, 2015) was used to calculate the model. *Session length* was included as dependent variable, *whether or not the session starts with a notification, app event count per session, notification count per session, presence of social media apps in session, presence of communication apps in session, average session length per participant, total session count per participant, age* and *gender* were included as fixed effects. *Participant* (id) was included as random effect. The model was therefore specified as follows:

Session length ~ *app event count per session + session starts with a notification (Y/N)+ notification count per session + mean session length per participant + total session count per participant + age + gender + (1|Participant)*

Results

Descriptive statistics

Table 2 presents the descriptive statistics of the variables in the model.

Table 2. Descriptive statistics

	Overall (N=73250)
Session length (seconds)	
Mean (SD)	135 (253)
Median [Min, Max]	45.8 [1.00, 2250]
Session starts with notification	
No	62934 (85.9%)
Yes	10316 (14.1%)
Session's # app events	
Mean (SD)	2.22 (1.77)
Median [Min, Max]	2.00 [1.00, 11.0]
Session's # notifications	
Mean (SD)	0.281 (0.577)
Median [Min, Max]	0 [0, 5.00]
Social media apps in session	
No	55055 (75.2%)
Yes	18195 (24.8%)
Communication apps in session	

	Overall (N=73250)
No	28315 (38.7%)
Yes	44935 (61.3%)
Participant's average session length	
Mean (SD)	135 (61.3)
Median [Min, Max]	115 [62.5, 574]
Participant's total session count	
Mean (SD)	782 (363)
Median [Min, Max]	766 [76.0, 1870]

Model results

The model's total explanatory power was moderate (conditional $R^2 = 0.15$). 13.7% of the variance was explained by the fixed effects alone (marginal R^2). The ICC, the proportion of the variance explained by the grouping structure in the population (participant), was low (0.02). Table 3 presents the model coefficients.

The more app events a session contained, the longer the session lasted. On average, per added app event, session length was found to increase by 41% on average ($\exp(\beta=0.34)=1.41$, $t(73238)=75.33$, $p < 0.001$). When a session started following a notification, it tended to be shorter than sessions that did not start with a notification ($\exp(\beta=-0.24)= 0.78$, $t(73238)= -8.81$, $p < 0.001$). More particularly, on average, a session that started following a notification was found to be 22% shorter than one that did not. Sessions containing social media apps were found to be on average 8% longer than sessions without social media apps ($\exp(\beta=0.081)= 1.08$, $t(73238)= 4.93$, $p < 0.001$). A participant's average session length ($\exp(\beta=0.005)= 1.01$, $t(73238)= 13.5963$, $p < 0.001$) and total session count ($\exp(\beta=-0.0002)= 0.99$, $t(73238)= -2.37$, $p = 0.018$) over the logging period significantly predicted the session length. Age appeared to have a moderate effect on session length ($\exp(\beta=-0.003)= 0.997$, $t(73238)=$, $p < 0.089$). Per added year, the expected session length decreased by 0.3%. This effect was only significant at the 90%-level, however. The amount of notifications received during a session, the presence of communication apps in the session and gender did not affect session length.

Table 3. Model coefficients

	Session length			
Fixed effects	*Estimates*	*CI*	*t*	*p*
(Intercept)	3.525	3.245 – 3.806	24.674	**<0.001**
Session starts with notification (True)	-0.243	-0.298 – -0.189	-8.811	**<0.001**
Session's # app events	0.340	0.331 – 0.349	75.329	**<0.001**
Session's # notifications	-0.002	-0.036 – 0.032	-0.123	0.902
Social media apps in session (Yes)	0.081	0.049 – 0.113	4.933	**<0.001**
Communication apps in session (Yes)	0.002	-0.027 – 0.032	0.162	0.871
Participant's average session length	0.005	0.004 – 0.005	13.596	**<0.001**
Participant's total session count	-0.0002	-0.0004 – -0.00004	-2.373	**0.018**
Gender (Female)	-0.039	-0.140 – 0.061	-0.766	0.444
Age	-0.003	-0.007 – 0.001	-1.701	0.089
Random Effects				
σ^2	3.19			
$\tau_{00\ id}$	0.06			
ICC	0.02			
N_{id}	125			
Observations	73250			
Marginal R^2 / Conditional R^2	0.137 / 0.154			

Discussion and limitations

The results present interesting micro-level findings on the factors that drive smartphone use duration. Overall, the findings show that when a session starts with a notification, we can expect it to be 22% shorter than sessions not starting with a notification. This suggests that smartphone that is initiated by a notification is more likely to unfold as a quick verification of the content of the initial notification, whereas sessions that do not start from a notification may present more intentional smartphone use.

In contrast to Kim et al. (2016), we did not find evidence that an increase in the number of notifications results in higher session duration. Similar to Sha et al. (2019), however, we did find that the presence of social media apps in a session resulted in an expected 8% longer session compared to sessions without social media apps. A limitation is that we only considered whether the session contained one or more versus no social media apps. Repeated use of the same social media app, alternated with other apps was therefore smoothed out. The same effect was not found for communication apps. This suggests that, although communication and social media apps are both generally geared towards 'connecting with other people', they do bring a different set of affordances to the user, with especially social media apps offering greater opportunities for passive consumption of contents.

We controlled for the participant's average session length and the participant's total session count. Unsurprisingly, both drive smartphone duration, albeit their effects are small. While we expected age to have a significant effect on session duration, only limited evidence was found. Our sample does not accurately represent the population in terms of age distribution, however. It is likely that a higher representation of older age categories would yield different results here. Other limitations are the limited sample size (N= 125). Furthermore, this study presents an exploratory model and calls for extensions to more accurately model session duration. Adding more app categories in order to assess differential impacts of app types on session length could be a first addition. Moreover, we considered all notifications equally. Further research may distinguish between notifications from different app types. It is likely that notifications from social media have different impact on session length compared to notifications from news applications for example. Lastly, exploration of various interaction and random effects may bring more nuance to this exploratory model.

Conclusion

This study presents the results of an exploratory model that quantifies the impact of various smartphone use characteristics on smartphone usage duration. The results can contribute to research focused at assessing the impact of smartphone use and/or notifications on issues such as attention disruption, screen time analysis and psychological wellbeing. Moreover, it presents a methodological contribution by demonstrating how detailed smartphone log data can be used in computational modeling of smartphone use by means of Generalized Linear Mixed Effects Models.

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