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Chapter 11
Studying Psychopathology in Relation to Smartphone Use

Dmitri Rozgonjuk, Jon D. Elhai and Brian J. Hall

Abstract Smartphones allow for several daily life enhancements and productivity improvements. Yet, over the last decade the concern regarding daily life adversities in relation to excessive smartphone use have been raised. This type of behavior has been regarded as "problematic smartphone use" (PSU) to describe the effects resembling a behavioral addiction. In addition to other daily life adversities, research has consistently shown that PSU is related to various psychopathology constructs. The aim of this chapter is to provide an overview of some findings in PSU research regarding associations with psychopathology. We also discuss some of the theoretical explanations that may be helpful in conceptualizing PSU. We then take a look at self-reported PSU in relation to objectively measured smartphone use, and, finally, provide some insight into current findings and future opportunities in objectively measuring smartphone use in relation to psychopathology measures. This chapter may be useful as an introductory overview into the field of PSU research.

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11.1 Introduction

Smartphones provide many advantages to society that were unthinkable before the mid-to late 2000s. In addition to the traditional voice calls and text messages, smartphones are essentially small computers that provide access to the Internet and various applications with utility ranging from productivity enhancement to entertainment. These features, in fact, have the capability to facilitate important daily activities. Furthermore, with a smartphone, one may purchase their meals, clothing, or other necessary items without actually stepping into a physical store. These activities can be conducted almost anywhere, anytime.

In fact, because smartphones allow for efficient connectivity and even the replacement of many in-person, face-to-face daily-life activities, people may increasingly opt for using smartphones to execute their tasks. This preference may be associated with more frequent smartphone use as a result. Excessive engagement with smartphones, however, can be associated with several detrimental daily life conditions. In this chapter, we introduce problematic smartphone use, describe how smartphone use may be related to psychopathology, review how studies have implemented objectively measured smartphone use coupled with psychopathology constructs, and explore how smartphone features could be used in psychopathology research.

11.2 Problematic Smartphone Use and Smartphone Addiction

Soon after the initial emergence of smartphones, concern about people spending excessive time on their devices was raised. In fact, such concern was already raised during the pre-smartphone era with internet use (Young 1996; Young and Rogers 1998), and with earlier mobile phones (Bianchi and Phillips 2005). However, smartphone ownership quickly became prevalent in modern society. The extreme portability and easy accessibility may have lead some people to engage in excessive smartphone use.

Smartphone "addiction" is not recognized as a bona fide disorder. Nonetheless, it is an important construct that is studied in the scientific literature. Some research uses the term "smartphone addiction" (Kwon et al. 2013a), or similarly "proneness to smartphone addiction" (Rozgonjuk et al. 2016). More recently, researchers tend to avoid labeling this construct as an "addiction," instead using alternate labels such as smartphone overuse (Lee et al. 2017), and excessive smartphone use (Chen et al. 2016). Most recently, this construct was conceptualized and labeled as "problematic smartphone use" (PSU) to emphasize the adversity related to excessive smartphone

use, and avoid addiction terminology (Panova and Carbonell 2018). PSU could be described by some emotional, cognitive, and behavioral difficulties associated with smartphone use. Frequently, the framework inspired by addiction research has been implemented, suggesting that PSU could be characterized by symptoms such as withdrawal (negative affect when separated from one's smartphone), tolerance (failed attempts to reduce smartphone use), and daily-life disturbances (impairment at work/school and/or health problems), among others (Kwon et al. 2013a). However, it should be noted that by using "problematic smartphone use" as the term describing similar conditions (e.g., smartphone addiction), there is still no consensus regarding using this term. One possible reason is that "problematic" could either describe a person being on the way from "healthy" to experiencing full blown psychopathological symptoms, or it could be the end condition in itself. Therefore, another used term is "smartphone use disorder" (Lachmann et al. 2018; Sha et al. 2019). With that being said, we will continue using the "problematic smartphone use" terminology in this text, while acknowledging that debate regarding vocabulary is ongoing.

How exactly is this *problematic* condition measured? Typically, self-report measures (questionnaires) were used. For example, measures such as the Smartphone Addiction Scale, developed by Kwon et al. (2013a, b), include symptom-based items adapted from substance use disorder scales and criteria, which assessed functional impairments associated with PSU. This questionnaire, and its shorter version (Kwon et al. 2013a, b), are probably the most commonly used contemporary instruments for measuring PSU, and have evidenced adequate psychometric properties (Demirci et al. 2014; Lopez-Fernandez 2017).

Mental health problems related to (self-reported) PSU are reported across different cultures, ranging from the Americas (Khoury et al. 2017; Elhai et al. 2018a), Europe (Lopez-Fernandez et al. 2017), and Asia (Kwon et al. 2013b). Apparently, concerns regarding PSU have been raised almost all over the world, further emphasizing the need for understanding this phenomenon. We now focus more specifically on mental health-related correlates of PSU.

11.3 How May Psychopathology Relate to Increased Smartphone Use?

To answer how and why psychopathology may be related to increased smartphone use and PSU, it would be reasonable to discuss several theories that conceptualize digital technology and media engagement. Specifically, we first discuss Uses and Gratifications Theory (UGT; Blumler 1979) and Compensatory Internet Use Theory (CIUT; Kardefelt-Winther 2014).

UGT posits that people actively seek out specific media to satisfy their psychological needs (Blumler 1979). These particular needs are the main drivers of certain types of media selection (Sundar and Limperos 2013; Rubin 2009). There are several gratifications, or need satisfactions, that people could obtain from their mobile

phones, such as social need fulfillment, seeking information online, relaxation, and mobility (Sundar and Limperos 2013). Broadly, gratifications have been divided into three typologies: content (obtained from media content, e.g., reading news), process (from using the media, e.g., surfing the web), and social (media as a social environment, e.g., communicating with others) (Stafford et al. 2004). Derived from these gratifications, different media may have respective uses. In a study by van Deursen and colleagues (2015), smartphone use has broadly been categorized into process and social use, and shown that PSU was related to process, but not social smartphone use. On the other hand, there are also studies that show the prevalent role of social media use in developing PSU (Lopez-Fernandez et al. 2017; Rozgonjuk et al. 2018a; Sha et al. 2019, p. 201).

Another relevant tenet of UGT is that there are individual differences in engagement with media (Blumler 1979). In other words, levels of motivation to satisfy one's needs, but also differences in personality traits may drive some people to engage in higher levels of smartphone use. Regarding personality traits, it has recently been demonstrated that lower willpower may reflect the core vulnerability towards developing addictive tendencies towards digital technologies (Lachmann et al. 2017). Extraversion was shown to be positively and conscientiousness negatively correlated with social media engagement (Montag et al. 2015a, b). In addition, biological factors, such as age and sex of the smartphone user, may drive differences in engagement (Andone et al. 2016a). Another relevant factor of these individual differences may manifest in how people cope with experiencing negative affect. Here, CIUT is useful to conceptualize why some people engage in higher levels of digital technology use such as smartphones. According to CIUT, people may engage in excessive technology use in order to alleviate negative affect. In other words, some people who experience stressful life events cope with their negative emotions by using their smartphones (Kardefelt-Winther 2014). In fact, the SAS by Kwon et al. (2013a, b) (Wang et al. 2015; Zhitomirsky-Geffet and Blau 2016; Elhai et al. 2018b), includes items such as "Being able to get rid of stress with a smartphone" and "Feeling calm and cozy while using a smartphone", suggesting that emotion regulation may be a central motive for engaging in smartphone use. CIUT has been used to conceptualize psychopathology in relation to PSU (Wang et al. 2015; Zhitomirsky-Geffet and Blau 2016; Elhai et al. 2018c).

A more comprehensive approach explaining the associations between digital technology engagement and other psychological and environmental variables is the Interaction of Person-Affect-Cognition-Execution (I-PACE) model of specific Internet-use disorders by Brand and collegues (2016). Based on the cognitive-behavioral model of pathological Internet use by Davis (2001), and further developed from Brand and collegues (2014), the I-PACE takes the process approach regarding the development of digital technology addictions. According to the I-PACE model, individual differences in predisposing variables, such as personality traits, genetics, and psychopathology, drive the affective and cognitive responses to stimuli. These responses interact with the individual's coping and decision-making that results in the use of certain Internet-based media and platforms. In some cases, this may result in problematic digital technology use, such as PSU. In fact, some recent studies have used

the I-PACE model as a theoretical framework in explaining the associations between daily-life adversities and PSU (Montag et al. 2016; Duke and Montag 2017; Carvalho et al. 2018).

Recent findings have consistently demonstrated that PSU is associated with increased severity of mental disorders, mainly mood-related. PSU severity is related to increased severity of depression and anxiety (Elhai et al. 2017), including social anxiety (Elhai et al. 2018b), PTSD symptoms (Contractor et al. 2017a), and stress (Wang et al. 2015). In addition, PSU has been associated with the so-called "transdiagnostic constructs". These are psychopathology-related characteristics that tend to overlap between different mental disorders (e.g., mood and anxiety disorders) and are considered to be core vulnerability factors in mental disorders (Krueger and Eaton 2015). Studies have found that PSU is associated with impulsivity (Contractor et al. 2017b), boredom proneness (Elhai et al. 2018d), procrastination (Rozgonjuk et al. 2018a), anger and worry (Elhai et al. 2019), and lower distress tolerance and mindfulness (Elhai et al. 2018d). Althogether, these studies suggest that PSU is related to psychopathology severity, and that smarphone use has been shown to have detrimental effects on daily-life social situations (Dwyer et al. 2018; Kushlev et al. 2019). Finally, works on the associations between (excessive) digital technology use and different cognitive functioning domains (attention, memory, delay of gratification) show that more engagement is typically associated with poorer cognitive functioning (Wilmer et al. 2017), possibly explaining the link between smartphone use and ADHD symptoms (Kushlev et al. 2016).

To summarize, people differ in their motives for using various digital technologies, including smartphones. Yet, prevailing explanations indicate that seeking gratifications, and alleviating negative affect, are a central component of technology engagement. Findings in PSU studies have consistently demonstrated that one's affect regulation and ability to cope with stressful situations could be one of the most important factors driving problematic technology use and in turn increase mental burden as theorized by vicious cycle models.

11.4 Objectively Measured Smartphone Use (OMSU)

Limitations of the research discussed above include that the majority relied on cross-sectional designs. Additionally, most of these studies used self-report measures rather than measuring smartphone use objectively.

Measuring smartphone use objectively, for example by using specific apps measuring smartphone use frequency and data, could allow us to overcome the two main limitations of smartphone use studies. It was previously demonstrated that self-reported smartphone use is typically inaccurately estimated when compared to objectively measured smartphone use (Boase and Ling 2013; Montag et al. 2015a, b; Andrews et al. 2015). Therefore, for the purpose of studying psychopathology's relations with digital technology engagement, using recorded behavioral measures

may provide a more valid insight into smartphone engagement (Miller 2012; Yarkoni 2012; Andone et al. 2016b).

Probably the most straightforward approach to measure smartphone use is to measure actual time spent using smartphones and the number of phone checks/screen unlocks. These measures should provide information on (a) how much time one spends on their smartphone (usage duration), and (b) how frequently one initiates interactions with their smartphone (usage initiation frequency). Phone-checking and time spent using smartphones (reflected as active screen time) are shown to be two separate behavioral measures (Wilcockson et al. 2018; Rozgonjuk et al. 2018b). Whereas the former may indicate more active engagement with a smartphone (e.g., checking for messages), the latter could reflect more passive content consumption (e.g., watching videos, browsing social media sites). Based on the content of this chapter, one may have the following questions: (1) how is PSU related to OMSU, and (2) how are other psychopathological conditions associated with objectively measured behavior?

As mentioned earlier, actual smartphone use is not strongly correlated with self-reported smartphone use (Boase and Ling 2013; Andrews et al. 2015). Results from studying relations between PSU and objective behavioral smartphone use data are mixed. For instance, while Lin et al. (2017) found that both smartphone frequency (smartphone checking) and duration were associated with PSU severity, Rozgonjuk and collegues (2018b) found that only duration but not frequency was associated with PSU. The latter findings are further supported by Lin et al. (2015) who found phone checking behavior related to PSU severity. These studies support the notion that phone checking behavior and time spent on smartphones are distinct behavioral measures, and that the behavioral manifestation of PSU could be screen time. However, we should note that Wilcockson et al. (2018) did not find a relationship between the measures of PSU and OMSU. In addition, evidence from a recent study suggested the possibility that genetic differences in predisposition for social behavior may be associated with more active phone usage (Sariyska et al. 2018).

Beyond this relatively straightforward approach, contextual data could provide additional insights into PSU's relations with actual smartphone use behavior. Over the last years, the feasibility of objectively observing smartphone use behavior improved significantly. One of the reasons is that it is now possible to retrieve and analyze various smartphone use logs stored on one's device. This has also provided the opportunity to analyze people's behavior from actually recorded, or objectively measured, data. For instance, these objectively measured phone use data have been applied for personality research, predicting either phone use behavior from (self-reported) personality measures, or vice versa (Chittaranjan et al. 2013; Montag et al. 2014; Stachl et al. 2017).

One of the aspects to consider in this context is also the distinction between the frequency and duration of specific app usage on one's smartphone. A study by Ahn and collegues (2014) showed that different application categories and time of day may be indicative of problematic technology use. Specifically, differences in usage time and frequency of social networking sites (SNS) were associated with PSU. This seems logical, as one of the main uses of smartphones is to access and consume social

media and SNS, and excessive social media use has been regarded as a vulnerability factor for developing PSU (Lopez-Fernandez et al. 2017). However, Montag et al. (2017) showed that objectively measured Facebook use duration in one's smartphone may be a more reliable measure in relation to other outcomes, such as the gray matter volume of nucleus accumbens (often regarded as the brain's reward center).

While the literature on OMSU and other constructs, including PSU, is increasing, there is still a lack of studies implementing recorded, or objectively measured, data to measure behavioral outcomes. Yet, we believe that the improving feasibility of retrieving these data will introduce a richer and larger body of research in the upcoming years.

11.5 Objectively Measured Smartphone Use (OMSU) in Relation to Psychopathology

We discussed some of the findings between both OMSU frequency and duration and PSU, but how are these OMSU data related to psychopathology? Probably the most studied relationship is between increased smartphone use and depression severity. Here, too, findings are mixed. For example Saeb et al. (2015), found that both smartphone use duration and frequency are positively associated with specific psychopathology severity (depression). A study conducted among bipolar disorder patients found that while a depressive state was related to more screen time, a manic state was related to more frequent smartphone use (Faurholt-Jepsen et al. 2016). In addition, Elhai and collegues (2018a, b, c, d) found that maladaptive emotion regulation, a transdiagnostic construct, was associated with higher baseline smartphone use duration. However, studies also found the opposite. Specifically, the aforementioned study by Elhai and collegues (2018a, b, c, d) also demonstrated that lower depression severity predicted increased smartphone use duration over one week; and Rozgonjuk et al. (2018c) found that smartphone use duration was not predicted by depression, but lower depression severity was predictive of higher phone checking behavior.

Literature suggests that OMSU is related to severity of mood-related disorders. Even within those relationships, the number of studies is relatively small and there are mixed results, mainly due to methodological differences (Dogan et al. 2017). We mentioned some studies that investigated depression and bipolar disorder. However, the role of anxiety has also been investigated, with it not being a significant predictor of OMSU (Rozgonjuk et al. 2018b). Research on other disorders in relation to OMSU is scarce.

In conclusion, the number of studies where PSU, psychopathology and OMSU have been of interest, is small. A majority of those studies have investigated how mood-related disorders, such as depression, are related to smartphone use behavior. These studies suggest that the duration of smartphone use is associated with higher intensity of depressive symptoms. It would be interesting to see how OMSU is related to psychopathology other than mood-related disorders.

11.6 Using Smartphone Features to Measure Psychopathology

Another less-explored avenue in smartphone use and psychopathology research is sensor data use. Contemporary smartphones include many sensors that could track the user's mobility and environmental conditions. These sensors could also be helpful in both measuring PSU and the relationship between smartphone use and psychopathology. Below we will outline some ideas that might be helpful in studying psychopathology by using one's smartphone sensors. In order to execute these ideas, one probably needs to use third-party applications that retrieve relevant sensor data and that makes data export feasible.

Contemporary smartphones typically include an ambient light sensor that measures light in the room (or outside); typically the purpose of this sensor is to adjust the smartphone's screen brightness according to current lighting conditions. It could also be used to capture light levels of the environment in which the person is spending time. There is evidence that depression severity is related to the perception of ambient light, with higher depression levels predicting dimmer light perception (Friberg and Borrero 2000). However, those findings relied on self-report, rather than objective measures. Ambient light sensor data from smartphones could provide further validation to these results. Additional research questions would be to test how frequently and for how long do depressed people spend time in dim environments while *using* their smartphone. This idea stems from findings where PSU and social media use are associated with poorer sleep quality (Woods and Scott 2016). Finally, light density could also inform us about people's sleep-wake cycles which are typically disturbed in depressive disorders (Dogan et al. 2017). This research might help in developing prevention and intervention approaches to the individuals in need.

Microphones in smartphones could help in studying the effects of noise on a person's well-being. Noise is related to poorer sleep quality and more annoyance (Basner et al. 2014); noise annoyance has also been linked to depression and anxiety (Beutel et al. 2016). Again, smartphones could assist research in that domain by recording the noise levels of a person's surroundings. This research could be helpful in studying the relationship between physical noise and psychopathology. Microphones could also be useful in stress recognition. For example, an application called StressSense (Lu et al. 2012) was developed for that function. This application is relatively intrusive, though, requiring recording audio and video conversations of the user. Another potential utilization of microphones could be in speech, language, and voice analysis (Rathner et al. 2018a, b; Cummings and Schuller 2019). For example, it is possible to infer a person's sentiment through word use (Rathner et al. 2018b), and similarly, psychopathological tendencies, such as depression, ancxiety, and narcissism could be detected by the use of social words (Rathner et al. 2018a).

Weather could influence how people feel, with negative affect and/or fatigue being generally more experienced in colder and darker environments (Kööts et al. 2011). Contemporary smartphones may include a thermometer that tracks temperature of the

surrounding environment, while a barometer provides data about atmospheric pressure, another factor shown to influence fatigue (Denissen et al. 2008) and migraine headaches (Kimoto et al. 2011). Again, the mentioned studies have either mainly relied on subjective self-report data and/or more aggregate meteorological data from a local or national meteorological centre. Thermometers and barometers embedded into one's smartphone may provide more accurate, temporal data on these environmental factors and their relations to mood changes and potential psychopathology.

Levels of physical activity and mobility could be measured with a smartphone's accelerometer. This sensor can be found in fitness trackers as well as in smartphones. Accelerometers provide data that could inform about one's number of steps walked/run, flights of stairs climbed, and miles traveled by foot during a given day. Smartphone apps based on this sensor tend to be quite accurate in providing information about the user's steps (Case et al. 2015). Little or no physical activity is generally associated with poorer mental health (Hiles et al. 2017). Using the data from accelerometers could help in that line of research. In addition, investigating smartphone user's gait patterns (gait acceleration and walking speed) over a period of time might also be indicative of a person's affective state and potential psychopathology. Some support for these relationships are provided in the scientific literature where more sadness and depression were associated with reduced walking speed (Michalak et al. 2009). Additionally, different wearables (e.g., a smartwatch) could complement smartphone data by providing additional measures such as heart rate. This, more direct index of physical activity could help in discriminating between a regular walk and a physical exercise session, further specifying the smartphone user's physical activity patterns.

Another feature that provides insight into one's mobility is the global positioning system (GPS). GPS utilizes satellite technology in order to calculate and pinpoint one's location. This technology also allows for investigating the smartphone user's mobility patterns by foot or vehicle. While GPS might provide more accurate data of one's mobility, another (but less accurate) method to track one's mobility is to investigate movement between cell towers. Moving between cell towers basically means that a person (and their smartphone) will be changing their geographical location between the reception areas of different cell phone signalling towers. For instance, in a study by Faurholt-Jepsen et al. (2016) with bipolar disorder patients, depressive states were related to less movement between cell towers, while more severe manic symptoms predicted more movement between cell towers. In other words, while depressive symptoms may be related to less mobility, psychological states including higher arousal could be manifested in more mobility. The idea that people who are in a depressive phase are expected to travel and stay outside less often is also demonstrated in a study by Gruenerbl et al. (2014). Location data could also provide more insight about a person's whereabouts and the time spent at a specific location, which could be associated with other addictive behavior comorbidities, like alcohol use in relation to proximity or duration in a bar.

Of course, the combination of the aforementioned utilities could provide a more accurate and valid representation of one's mental health condition. Elaborate machine learning algorithms that include smartphone usage frequency and duration, different

sensors' data, and external factors (e.g., socio-demographic data, date and time of day of smartphone usage, additional self-reported measures, etc.) have been developed to predict smartphone users' negative affective states (Hung et al. 2016) and stress (Reimer et al. 2017) [and suicide—Nock].

In summary, in this section we described some of the opportunities of utilizing smartphone features and sensors to investigate affective states and potential psychopathology. While the list of sensors, and certainly the list of research questions, is not exhaustive, we find that there is an abundance of options for conducting research that include objective behavioral data retrieved from smartphones. Including objective behavioral data could provide a ground for replicating and validating previous research findings in psychopathology studies that mostly rely on self-report and cross-sectional study designs.

11.7 Concluding Remarks

Smartphones have enhanced people's everyday lives by providing means for ubiquitous communication, information consumption, and productivity enhancement. However, excessive engagement in smartphone use has been associated with psychopathology. People who experience stress may try to cope with negative emotions by seeking gratifications provided by smartphone use. This hypothesis is, to some extent, supported by findings from several studies where PSU was associated with psychopathology symptoms and other core vulnerabilities driving those forms of psychopathology. In addition to measuring smartphone use duration and frequency, other features of smartphones could be helpful in studying psychopathology.

This line of research could also provide some academic and clinical implications. As mentioned in this text, there is a relatively small number of studies that objectively measured smartphone use and correlated these results to measures of psychopathology and PSU. Objectively measuring smartphone use may specify the relations between engagement in digital technology use and mental health. This type of measurement could also be useful in clinical settings, as knowing who, how, and why people engage in more digital technology use may help in intervention and prevention of mental illness.

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