Journal of Affective Disorders 207 (2017) 251–259

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

# Problematic smartphone use: A conceptual overview and systematic review of relations with anxiety and depression psychopathology☆

Jon D. Elhai[a,b,*], Robert D. Dvorak[c], Jason C. Levine[a], Brian J. Hall[d,e]

[a] Department of Psychology, University of Toledo, Toledo, OH, USA
[b] Department of Psychiatry, University of Toledo, Toledo, OH, USA
[c] Department of Psychology, University of Central Florida, USA
[d] Department of Psychology, University of Macau, Taipa, Macau (SAR), People's Republic of China
[e] Department of Health, Behavior and Society, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

ARTICLE INFO

*Keywords:*
Psychopathology
Mental disorders
Information technology
Mobile phones
Addictions
Internet addiction

ABSTRACT

*Background:* Research literature on problematic smartphone use, or smartphone addiction, has proliferated. However, relationships with existing categories of psychopathology are not well defined. We discuss the concept of problematic smartphone use, including possible causal pathways to such use.

*Method:* We conducted a systematic review of the relationship between problematic use with psychopathology. Using scholarly bibliographic databases, we screened 117 total citations, resulting in 23 peer-reviewer papers examining statistical relations between standardized measures of problematic smartphone use/use severity and the severity of psychopathology.

*Results:* Most papers examined problematic use in relation to depression, anxiety, chronic stress and/or low self-esteem. Across this literature, without statistically adjusting for other relevant variables, depression severity was consistently related to problematic smartphone use, demonstrating at least medium effect sizes. Anxiety was also consistently related to problem use, but with small effect sizes. Stress was somewhat consistently related, with small to medium effects. Self-esteem was inconsistently related, with small to medium effects when found. Statistically adjusting for other relevant variables yielded similar but somewhat smaller effects.

*Limitations:* We only included correlational studies in our systematic review, but address the few relevant experimental studies also.

*Conclusions:* We discuss causal explanations for relationships between problem smartphone use and psychopathology.

## 1. Introduction

In recent years, mobile phones have become pervasively used globally (Pew Research Center, 2014, February 13). Despite the social networking advantages (Cho, 2015) and productivity enhancements from using mobile phones – smartphones in particular – a growing literature finds many people overuse their phones in ways that interfere with their daily lives (Cheever et al., 2014; Clayton et al., 2015). Problematic mobile phone use is associated with health hazards, such as texting while driving, leading to injury and death (reviewed in Cazzulino et al., 2014), and types of psychopathology, including anxiety and depression (e.g., Demirci et al., 2015; Kim et al., 2015a).

We present a conceptual review of problematic smartphone use. Next, to identify psychopathological correlates of problematic smartphone use, we conducted a systematic literature review and synthesis on relations between problem use – for smartphones, more specifically - and psychopathology. This review is aimed at synthesizing the diverse individual studies and their findings in this area, to derive overall conclusions on the problem smartphone use-psychopathology relationship. No such summary or synthesis has been available before in this area, leaving the reader to consider individual study findings, without a comprehensive snapshot of the literature as a whole. We make a point of going beyond a discussion of statistical significance, by focusing on effect sizes from these studies.

## 2. Background

The introduction of the iPhone to global markets in 2007 marked a

☆ We thank David Medina, PhD, for providing feedback on an earlier draft of this paper.
* Corresponding author at: Department of Psychology, University of Toledo, Mail Stop #948, 2801 W. Bancroft St., Toledo, OH 43606-3390, USA.
*E-mail address:* contact@jon-elhai.com (J.D. Elhai).

http://dx.doi.org/10.1016/j.jad.2016.08.030
Received 25 February 2016; Received in revised form 30 April 2016; Accepted 27 August 2016
Available online 02 October 2016

substantial and radical change in the mobile industry, and in subsequent mobile phone products, because of numerous technological advancements that came with it (Frommer, 2011, June 6). Based on a typology of internet uses and applications (Song et al., 2004), smartphone uses can be similarly categorized as follows: productivity enhancement (e.g., calendar and email), information seeking (e.g., web browsing news stories), social information and interaction (e.g., social media), diversion and relaxation, entertainment, monetary compensation (e.g., locating consumer deals) and personal status (van Deursen et al., 2015). Importantly, smartphones are compact and light, fitting into one's pocket or purse for easy accessibility.

A national opinion poll study released in 2015 by the non-partisan Pew Research Center (Smith and Page, 2015, April 1) sampled more than 3000 American adult cellphone users, finding roughly two-thirds owned a smartphone. A subset of about 1000 participants was followed for one week in an experience sampling study of smartphone use. During the week of observation, the most prevalent (non-mutually exclusive) smartphone uses included texting (97%), voice or video calls (92%), internet browsing (89%), email (88%), and social network site use (75%).

Despite the many uses and advantages of smartphones, there are disadvantages. This review focuses on mental health correlates of problem smartphone use, but there are additional health hazards worth noting. Smartphones can distract drivers (especially young adults) who talk or text on the phone while driving, potentially leading to traffic accidents (reviewed in Cazzulino et al., 2014). Smartphone use is also a distractor among pedestrians while walking or crossing the street (Schwebel et al., 2012; Thompson et al., 2013). Smartphone use is associated with neck and shoulder pain because of one's posture while using a smartphone (Shan et al., 2013; Xie et al., in press), as well as hand dysfunction (İNal et al., 2015). Mobile phone use in students is associated with poor physical fitness (Lepp et al., 2013; Rebold et al., 2016), and worse academic performance (Jacobsen and Forste, 2011; Lepp et al., 2014; Prabu et al., 2015). Greater problem use can expose individuals to more hazards or negative effects.

## 3. The addiction construct in relation to smartphone use

In the Pew Research study, 46% of smartphone owners indicated that they "couldn't live without" their phone (Smith and Page, 2015, April 1). When separated from their smartphones, many individuals evidence mounting anxiety (Cheever et al., 2014) and physiological withdrawal-like symptoms (Clayton et al., 2015). In fact, many individuals experience phantom cell phone vibrations even in the absence of incoming phone notifications (Kruger and Djerf, 2016). In addition to "problematic smartphone use," other terms that have been used to describe this construct regarding a smartphone include "addiction," "excessive use," "compulsive use," and "compensatory use" (Kardefelt-Winther, 2014; Widyanto and Griffiths, 2006). "Compensatory use" may not be exactly the same as problematic use, but clarifies the motivation of such use – that is, to escape real-world problems and duties, and/or avoid negative emotion and affect (Kardefelt-Winther, 2014).

Problematic smartphone use has some communalities, but also differences, with other related constructs, such as internet addiction (reviewed in Kuss et al., 2014) and internet gaming addiction (reviewed in Kuss and Griffiths, 2012). These constructs have similar symptoms in common, typically measured using substance-related items with functional impairment. However, problematic smartphone use is different primarily because of the platform and interface of a smartphone. The internet addiction literature burgeoned before smartphones became prevalent – i.e., during times when it was not possible to use the internet, games or other web services on one's phone. The portability and accessibility of such smartphone uses and applications, discussed above, make the nature of problem smartphone use different from these other constructs. (And in fact, these constructs are statistically distinct from one another, Kiraly et al., 2014).

To understand the newer construct of problem smartphone use, it is helpful to first review addiction in the context of the more established behavior of substance use. Most prominent psychological models of addiction posit that compulsory use, or what might be termed "addiction," develops out of a process of positive and/or negative reinforcement (Robinson and Berridge, 2003). Negative reinforcement models, often referred to as "self-medication" or "affect regulation," suggest that addiction develops as a way to cope with negative emotion (Baker et al., 2004). Although negative reinforcement seems like an intuitive mechanism for addiction, supporting research has been inconsistent (Shiffman et al., 2002). Negative reinforcement may result in subconscious associations that prompt automatic motivation to engage in the behaviors (Baker et al., 2004) (e.g., through automatic "checking" for smartphone notifications). However, the inability to engage in this automatized behavior results in heightened levels of negative mood (Baker et al., 2004). Thus, negative reinforcement models offer a possible mechanism for use maintenance, but may not explain how one may progress from use initiation to pathological use.

More accepted in explaining how use progresses to pathological use are positive reinforcement models of addiction (primarily for substance use), such as incentive sensitization theory (Robinson and Berridge, 2001). This theory posits that addiction initially develops as a process of mood enhancement, where individuals enjoy, and eventually crave, the positive aspects of the compulsory behavior (Robinson and Berridge, 1993), such as notification checking. At the initial stages, this results in strong associative or Pavlovian learning, making individuals increasingly attuned to small cues that come to signal the reward received from the compulsive behavior. Eventually this produces a disconnect between "liking" engagement in the behavior and "wanting" engagement in the behavior (Robinson and Berridge, 2000). Consequently, individuals develop an attention bias to environmental cues that prompt them to engage in the compulsory behavior, producing an urge to chase the positive feelings that occurred in the initial stages of use.

Thus, pathological use, as in the case of problematic smartphone use, may begin as a process of positive reinforcement. As the behavior becomes more compulsory, the individual begins to experience negative mood when not engaging in the behavior (i.e., withdrawal). Consequently, the only way to relieve the withdrawal is by engaging in the behavior (Wise and Koob, 2014). Alternatively, another way to view positive and negative reinforcement in smartphone addiction is that both types of reinforcement similarly involve the craving of positive emotion to alleviate negative emotion. However, it is also important not to overpathologize smartphone use (Billieux et al., 2015b). Indeed, even within the drug use literature there is evidence that some levels of use are not detrimental, and in fact can be adaptive (Schulenberg et al., 2000; Shedler and Block, 1990).

Causal theories of problem smartphone use draw from models of internet addiction. Several important pathways that are broad in focus and most discussed in the literature are discussed below, though not necessarily an exhaustive list. Several pathways are related to negative reinforcement models: a) habitual use and checking behaviors (Oulasvirta et al., 2012); b) seeking excessive reassurance (Billieux et al., 2015a); and c) reluctance to miss important information or content (Przybylski et al., 2013). These pathways are relevant to negative reinforcement because they involve behaviors intended to alleviate negative emotion. Two additional pathways are relevant to both negative and positive reinforcement models because they involve hedonic behaviors intended to boost positive emotion, but also warding off negative emotion: d) extraversion and e) impulsivity (Billieux et al., 2015a). As previously noted (Billieux et al., 2015a) note, these pathways are not mutually exclusive.

The development of problematic smartphone use through habit involves the tendency for smartphone features such as notifications and alerts to serve as cues for automatic checking behavior of one's phone

(Oulasvirta et al., 2012). Over time, merely seeing the phone on the countertop or nightstand, for example, serves as a cue for frequent and repeated checking for notifications. And such habits serve as a gateway to increased, potentially problematic, smartphone use over time (Oulasvirta et al., 2012). Such habits of checking one's phone and observing notifications also serve in obtaining social reassurance behavior from friends and relationship partners – the "reassurance seeking" pathway (Billieux et al., 2015a). This reassurance seeking behavior can broadly include symptoms such as low self-esteem, loneliness, depression and anxiety that drive such reassurance seeking (Billieux et al., 2015a). Furthermore, checking behaviors are related to the next pathway, "fear of missing out" (FoMO).

FoMO involves the reluctance to miss important information and rewards, including social information. Thus people with FoMO often perceive the need to stay persistently connected with what others are doing in their social network. This construct was first discussed in the news media (Morford, 2010, August 4). Research demonstrates that FoMO appears to drive overuse of technology such as social media (Alt, 2015; Przybylski et al., 2013), as well as smartphones (Clayton et al., 2015).

Additional pathways toward problem smartphone use involve extraversion and impulsivity. The extraversion pathway involves social dependence-related symptoms, driving the individual to constantly maintain and establish *new* relationships, though without necessarily involving reassurance seeking from *existing* relationships (reviewed in Billieux et al., 2015a; also see Hoffner and Lee, 2015). This pathway can also involve sensation seeking and reward sensitivity (Billieux et al., 2015a). Finally, the impulsivity pathway involves lack of self-control and regulation in managing smartphone use (reviewed in Billieux et al., 2015a). This pathway is also relevant to antisocial personality traits, disinhibition, and attentional deficits (Billieux et al., 2015a). Evidence for such pathways derive from research, including structural equation models, finding associations between problem smartphone use and extraversion (e.g., Ehrenberg et al., 2008; Hong et al., 2012; Smetaniuk, 2014), impulsivity and lack of self-control (e.g., Jeong et al., 2016; Khang et al., 2013; Soror et al., 2015).

We should note that our discussion and organization above about pathways to problematic smartphone use is not an exhaustive list of pathways, and not the only way to organize pathways. Another way to organize these pathways could include: a) variables that involve personality traits on a continuum of normal-to-psychopathology (e.g., extraversion) that may or may not lead to problematic smartphone use; b) variables that are present among those already with problematic smartphone use (e.g., FoMO), and c) variables that are behavioral markers and may be problematic or could be productivity-conducive (e.g., habitual checking of a smartphone).

## 4. Aims

While these causal pathways elucidate the development of problem smartphone use, the study of psychopathological correlates of such use is a different issue. The primary purpose of the present paper is to synthesize findings on relationships between problematic smartphone use/use intensity with psychopathology severity using a systematic review. Systematic reviews are generally accepted as a common standard in healthcare research (Moher et al., 2015), and are increasingly common in contemporary times (Bastian et al., 2010).

We focused on the variables of both problematic smartphone use as well as the range of smartphone usage, because both have been examined in the literature. Furthermore, some theoretical models of problematic smartphone use assume that increased levels of use progress to problem use (Kim et al., 2015a; van Deursen et al., 2015); other models assume that problematic use leads to increased levels of use (Billieux et al., 2008; Hong et al., 2012). Despite a growing number of studies examining such relationships, no systematic review has previously been published, leaving a literature body of isolated findings.

## 5. Method

### 5.1. Search strategy

We conducted a systematic review of publications available from 2008 until September 21, 2015 to identify all relevant studies. As indicated above, the iPhone's debut in 2007 set the stage for a major advancement in mobile phone technology. Thus we included studies published after 2007 in order to analyze data from participants most likely to use smartphones rather than older cellular phones. Data collection and analysis proceeded in accordance with the PRISMA review guidelines (Moher et al., 2015).

We searched three comprehensive bibliographic databases: PsycINFO, PubMed, and Google Scholar. We used such search 3 terms as "cellular phone," "cell phone," "mobile devices," and "mobile phone," in combination with (using the "AND" Boolean operator) terms as "problem use," "compensatory use," "addiction," "internet addiction," and "smartphone addiction." After identifying and deleting the duplicates, citations and full text were imported into Endnote X7. We next reviewed reference lists from the resulting titles in order to locate additional relevant papers. Finally, we manually searched relevant journals for recently added content, including *Computers in Human Behavior*, and *Cyberpsychology, Behavior and Social Networking*.

### 5.2. Inclusion and exclusion criteria, and study selection

We required studies in our review to have the following characteristics: 1) published or "online first" in peer-reviewed journals; 2) written in English; 3) included a standardized instrument (i.e., administered in a consistent manner across subjects) measuring psychopathology; 4) included a standardized and/or quantifiable measure of smartphone/mobile phone addiction, or the continuum of usage; and 5) conducted inferential statistics examining relationships between psychopathology and phone addiction/usage. Studies were excluded that only examined internet addiction but not in the context of smartphone use.

We included studies that examined psychopathology variables that are incorporated into DSM-5 as clinical disorders, disorder categories, or symptoms of disorders. We also excluded studies that only examined personality (but not psychopathological) constructs such as loneliness, sensation-seeking, or impulsivity, in order to glean information about DSM-5-related psychopathology constructs. We chose psychopathology variables used in multiple studies (at least three), in order to draw generalizable conclusions based on adequate data.

We also excluded studies that used latent groups of individuals to examine psychopathology-phone addiction relationships (Lu et al., 2014; Mok et al., 2014). Additionally, when a study measured smartphone use/addiction in both dimensional and dichotomized formats, we present effect sizes based only on continuous data, due to statistical limitations with using dichotomized variables (MacCallum et al., 2002), and the lack of present diagnostic criteria or classification algorithms for problem smartphone use (for a discussion, see Lopez-Fernandez et al. (2014)).

Two study authors reviewed the titles and abstracts resulting from our search to identify relevant studies. Full-text papers were then assessed independently for relevance, and a third author discussed any disagreements. Data abstraction was completed by one author (JDE) who first created an excel sheet with all relevant information including study characteristics such as location of study, age category, sex, sample size, type of independent and dependent variables, and summary unadjusted and adjusted effect sizes.

**Table 1**
Study characteristics and results.

| *Study* | *Sample size* | *participants* | *Phone addiction/use variable(s)* | *Bivariate results with phone addiction/use* | *Multivariate results with phone addiction/use* |
|---|---|---|---|---|---|
| (Lepp et al., 2014) | 536 | College students | 1) Cell phone minutes per day<br>2) # Texts per day | 1) BAI scores r=.10*<br>2) BAI scores r=.09* | N/A |
| (Beranuy et al., 2009) | 404 | College students | CERM scores | SCL–90-R subscales: GSI r=.30*, PST r=.31*, PDSI r=.17* | N/A |
| (Lee et al., 2014) | 325 | Adults from community | Scores on scale of compulsive smartphone use | SIAS scores r=.44* | Adjusting for locus of control, materialism, and need for touch... SIAS beta=.12* |
| (Khang et al., 2013) | 290 | College students | Mobile phone addiction scores | N/A | Adjusting for self-efficacy and self-control... RSES beta=−.21* |
| (Jeong et al., 2016) | 944 | 6th grade students | Scores on adaptation of K scale | Stress scale r=.29* | Adjusting for gender, SCRS, BSSS, UCLA Loneliness Scale, media usage types (study, entertainment, games, social network use)... Stress scale beta=.10* |
| (Hong et al., 2012) | 216 | College students | 1) MPAS scores on Time Management<br>2) MPAS Academic Problems<br>3) MPAS Reality Substitute<br>4) Number of daily calls<br>5) 5) Number of daily sent texts | 1) LPAS Anxiety subscale r=.13*, RSES r=−.26*<br>2) Anxiety r=.27*, RSES r=−.24*<br>3) Anxiety r=.25*, RSES r=−.18*<br>4) Anxiety r=.21*, RSES r=−.10<br>5) Anxiety r .15*, RSES r=−.17* | (Predicting overall MPAS), adjusting for social extraversion... Anxiety beta=.23*, RSES beta=−.23* |
| (Kim et al., 2015b) | 351 | 6th grade students | MPOQ scores | STAI scores r=.30* | N/A |
| (Kim et al., 2014) | 795 | Elementary, middle and high school students | SAPS-Y scores | NEO Youth Personality Test-Mental Health Problems Score r=.43* | N/A |
| (Ehrenberg et al., 2008) | 200 | College students | 1) # of calls<br>2) # SMS<br>3) # IMs<br>4) MPAT scores<br>5) IMAT scores | N/A | Adjusting for NEO FFI scores on neuroticism, extraversion, agreeableness, conscientiousness...<br>1) CSI beta=.04<br>2) CSI beta=.07<br>3) CSI beta=−.28* 4) CSI beta=−04<br>4) CSI beta=−.28* |
| (Walsh et al., 2011) | 303 | College and high school students | 1) MPUBS score<br>2) MPIQ scores | 1) RSES r=−.05<br>2) RSES r=−.15* | Adjusting for age, gender, payment method, self-identity, in-group norms, need to belong...<br>1) RSES beta=−.01<br>2) RSES beta=−.08 |
| (van Deursen et al., 2015) | 386 | Internet survey panel adults | 1) MPPUS scores for habitual use<br>2) MPPUS scores for addictive use | 1) BFNES social stress scores r=.14*<br>2) BFNES social stress scores r=.33* | Adjusting for age, gender, process smartphone use, social smartphone use, emotional intelligence, and SRQ...<br>1) social stress beta=−.01<br>2) social stress beta=.13* |
| (Wang et al., 2015) | 600 | College students | SAS-C scores | For problematic smartphone users... PSS scores r=.33* | Across various models with different sets of predictors... PSS scores betas ranged from .19* to .31* |
| (Lee, 2015) | 304 | Black college students | SAS-SV scores | N/A | Adjusting for age, gender, IPIP traits of extraversion, agreeableness, neuroticism, conscientiousness, Facebook addiction and multitasking... SIAS beta=.31* |
| (Thomée et al., 2011) | 4156 | Randomly selected community sample | Combination of # phone calls + # SMS... Categorizing participants as low vs. high users | N/A | Adjusting for relationship status, education, occupation... Sleep item*, stress item*, 3-item depression survey* |
| (Ha et al., 2008) | 595 | Technical high school students | EC-PUS scores... Dichotomized into excessive vs. low users | BDI scores*, IAS scores*, lower RSES scores* | N/A |
| (Harwood et al., 2014) | 274 | Adults from email listservs, social networking sites, universities | 1) # texts<br>2) # calls<br>3) smart device use frequency<br>4) email frequency<br>5) 5) MPIQ smart device involvement scores | 1) DASS-21 anxiety r=.19*, stress (ns)<br>2) depression r=−.13*, stress (ns)<br>3) stress (ns), anxiety (ns), depression (ns)<br>4) stress (ns)<br>5) depression r=.24*, stress r=.27*, anxiety r=.24* | Across various models with different sets of predictors... Smart-device involvement predicted depression (beta=.15*), anxiety (beta=.12), stress (beta=.18*) |
| (Guzeller and Cosguner, 2012) | 950 | High school students | PMPUS scores | BDI r=.24* | N/A |
| (Augner and Hacker, | 206 | Technical college students | PU scores | N/A | Adjusting for age, gender, extraversion, emotional stability... Chronic |

*(continued on next page)*

**Table 1** *(continued)*

| *Study* | *Sample size* | *participants* | *Phone addiction/use variable(s)* | *Bivariate results with phone addiction/use* | *Multivariate results with phone addiction/use* |
|---|---|---|---|---|---|
| 2012) | | | | | Stress Inventory beta=.27*, WHO-5 depression beta=.15* |
| (Lu et al., 2011) | 213 | City office employees | 1) STDS Emotional reaction score<br>2) STDS Excessive use score<br>3) STDS Relationship maintenance score | 1) HADS anxiety score r=.07, HADS depression r=.32*<br>2) HADS anxiety r=.02, HADS depression r=.31*<br>3) HADS anxiety r=.16*, HADS depression r=.31* | Predicting a latent STDS factor, HADS depression beta=.48*, HADS anxiety beta=−.21* |
| (Smetaniuk, 2014) | 362 | College students | 1) ACPAT scores<br>2) MPPUS scores | 1) 1) ZSRD scores r=.43*, RSES scores r=−.27*<br>2) ZSRD r=.45*, RSES=−.27* | Adjusting for age, Extraversion Scale, Emotional Stability Scale, Impulse Control Scale.<br>1) ZSRD beta=.37*, RSES beta=.0<br>2) ZSRD beta=.34*, RSES beta=.05 |
| (Yen et al., 2009) | 1210 | Junior and high school students | PCPUQ high vs. low use | N/A | Adjusting for gender, age, residential area… CES-D high vs. low scores **unstandardized** beta=.94* (odds ratio=2.57) |
| (Demirci et al., 2015) | 319 | College students | SAS Scores | BDI r=.27*, BAI r=.28*, | Adjusting for age and gender… BDI beta=.07*, BAI beta=.09* |
| (Kim et al., 2015a) | 395 | Amazon Mechanical Turk Adult Subjects | PUMP (latent factor) | N/A | Adjusting for daily minutes cell phone usage, pass-time motivation and alleviation motivation to use mobile phone… CES-D (10-item version) beta=.18* |

Note: All beta weights are standardized, unless otherwise noted.

ACPAT=Adapted Cell Phone Addiction Test; BAI=Beck Anxiety Inventory; BFNES=Brief Fear of Negative Evaluation Scale; BSSS=Brief Sensation Seeking Scale; CERM=Cuestionario de Experiencias Relacionadas con el Móvil; CES-D=Center for Epidemiologic Studies Depression Scale; CSI=Coopersmith Self-Esteem Inventory; DASS-21=Depression Anxiety Stress-21 Scale; EC-PUS=Excessive Cellular Phone Use Survey; GSI=Global Severity Index; IAS=Interactional Anxiousness Scale; IM=Instant Messages; IMAT=Instant Message Addiction Tendencies Scale; IPIP=Mini-International Personality Item Pool; K Scale=Young's internet addiction scale; NA=Not Applicable; LPS=Lai's Personality Scale; MPAS=M-Smartphone Addiction Scale; MPAT=Mobile Phone Addiction Tendencies Scale; MPIQ=Mobile Phone Involves Questionnaire; MPOQ=Mobile Phone Overuse Questionnaire; MPPUS=Mobile Phone Problematic Use Scale; MPUBS=Mobile Phone Use Behaviors Scale; ns=Not significant (indicated if no effect size or coefficient provided by authors); NEO FFI=NEO Five Factor Inventory; PCPUQ=Problematic Cellular Phone Use Questionnaire; PDSI=Positive Symptom Distress Index; PMPUS=Problematic Mobile Phone Use Scale; PSS=Perceived Stress Scale; PST=Positive Symptom Total; PU=Problematic Mobile Phone Use; PUMP=Problematic Use of Mobile Phone measure; RSES=Rosenberg Self-Esteem Scale; SAPS-Y=Korean Smartphone Addiction Proneness Scale for Youth; SAS=Smartphone Addiction Scale; SAS-C=Smartphone Addiction Scale for College Students; SAS-SV=Smartphone Addiction Scale-Short Version; SCL-90-R=Symptom Checklist-90-Revised; SCRS=Self-Control Rating Scale; SIAS=Social Interaction Anxiety Scale; SMS = Short Message Service text messages; SRQ=The Self-Regulation Questionnaire; STAI=State Trait Anxiety Inventory; STDS=Self Perception of Text Messaging Dependency Scale; ZSRD=Zung Self-Rating Depression Scale.

* $p < .05$.

## 6. Results

### 6.1. Overall search findings

Our initial search yielded 117 titles. A total of 94 titles were excluded for studying assessment or intervention for substance use (n=44; 37.3%), not assessing psychopathology (n=26, 22.0%), not presenting empirical data (n=16, 13.6%), or not being written in English (n=8, 6.8%). Thus we had 23 titles in our review.

However, only six of these 23 titles explicitly distinguished between smartphone and non-smartphone use and indicated that their sample was composed exclusively of smartphone users. In terms of the likelihood of samples including participants with smartphones vs. older cellular phones, only four studies included (17.4%) were published before 2011 (but after 2007). Furthermore, most of the studies used college samples, and smartphone ownership among traditional college-age students is close to 100% (Poushter, 2016, February 22). Therefore, we also discuss effect sizes of more recent studies, below, in the Results section.

### 6.2. Methodological issues in the studies reviewed

We now report characteristics of the studies included in our review (indicated in Table 1). All studies had sample sizes of 200 or more reported for their analyses; two of which had samples greater than 1000 (Thomée et al., 2011; Yen et al., 2009). The average sample size was 623 participants (n=427 if excluding studies with more than 1000 participants). The majority of studies used exclusively students in college (n=10) or primary school (n=6). Other studies used non-student adults (n=5) (Kim et al., 2015a; Lee et al., 2014; Lu et al., 2011; Thomée et al., 2011; van Deursen et al., 2015), or a mix of samples (Harwood et al., 2014; Walsh et al., 2011). Studies were conducted in various countries, mostly including China (n=4) (Hong et al., 2012; Lee et al., 2014; Wang et al., 2015; Yen et al., 2009), Korea (n=4) (Ha et al., 2008; Jeong et al., 2016; Kim et al., 2014; Kim et al., 2015b), and the United States (n=4) (Khang et al., 2013; Kim et al., 2015a; Lee, 2015; Lepp et al., 2014; Smetaniuk, 2014).

The vast majority of studies included a standardized measure of problem smartphone use. Two studies did not measure problem use, but only the dimensionality of phone usage (Lepp et al., 2014; Thomée et al., 2011). While most studies examined problematic smartphone use as a continuous variable, two studies only examined dichotomized versions of such use (Ha et al., 2008; Yen et al., 2009).

Numerous problematic smartphone use/addiction scales were used across studies. Scales represented in more than one study each included the Mobile Phone Involvement Questionnaire, developed by Walsh et al. (2010), and used in two studies of psychopathology correlates (Harwood et al., 2014; Walsh et al., 2011). Also, the Smartphone Addiction Scale developed by Kwon et al. (2013b), or its short version developed by Kwon, Kim, Cho and Yang (2013a), were used in two studies (Demirci et al., 2015; Lee, 2015). Finally, the Mobile Phone Problematic Use Scale, developed by Bianchi and Phillips (2005), was used in two studies (Smetaniuk, 2014; van Deursen et al., 2015).

Most studies used bivariate (n=6), multiple regression (n=7) or both bivariate and regression analyses (n=10) to examine relations between smartphone use and psychopathology. Several studies used demographic variables as covariates of problematic smartphone use, including age (Smetaniuk, 2014) and gender (Jeong et al., 2016) – more commonly, both age and gender (Demirci et al., 2015; Lee, 2015; van Deursen et al., 2015; Walsh et al., 2011; Wang et al., 2015; Yen et al., 2009). In final regression models predicting problem smartphone use, mixed findings were apparent across studies for the statistical significance of age and gender; though age was associated with stronger effect sizes than gender. Gender's effect sizes were generally overshadowed by the psychopathology effect sizes within the regression models. Age's effect sizes were closer to the magnitude of the psychopathology correlates.

### 6.3. Main review findings

We structure our findings below, organizing them first by the use of well-validated instruments assessing psychopathology. Then we present effect sizes for relations between problematic smartphone use and the type of psychopathology considered. Because of the concern that some participants in these studies may have owned non-smart mobile phones, we also discuss effect sizes for studies published very recently – to be conservative, since 2014 ($n$=14).

#### 6.3.1. Depression

Ten studies assessed symptoms of depression (Augner and Hacker, 2012; Demirci et al., 2015; Guzeller and Cosguner, 2012; Ha et al., 2008; Harwood et al., 2014; Kim et al., 2015a; Lu et al., 2011; Smetaniuk, 2014; Thomée et al., 2011; Yen et al., 2009). Three of these studies used the Beck Depression Inventory (Demirci et al., 2015; Guzeller and Cosguner, 2012; Ha et al., 2008). The remaining studies used Zung's Self-Rating Depression Scale, Hospital Anxiety and Depression Scale, Depression Anxiety Stress Scale (DASS), World Health Organization-5 Depression Scale, or variations of the Patient Health Questionnaire or Center for Epidemiologic Studies-Depression Scale. Depression severity was significantly associated with problematic or general smartphone use, on a bivariate and multivariate basis in 9 of the 10 studies reviewed (Table 1). Bivariate correlations were typically in the range of .30–.40. Statistical adjustment in regression models yielded beta coefficients that were somewhat more varied, with several in the .30 to .50 range, but with several other coefficients somewhat lower. These results were quite similar when considering only the more recent studies – since 2014.

#### 6.3.2. Anxiety

Nine studies assessed symptoms of anxiety (Demirci et al., 2015; Ha et al., 2008; Harwood et al., 2014; Hong et al., 2012; Kim et al., 2015b; Lee, 2015; Lee et al., 2014; Lepp et al., 2014; Lu et al., 2011). Two studies used the Beck Anxiety Inventory (Demirci et al., 2015; Lepp et al., 2014), while others used social anxiety-related scales (Ha et al., 2008; Lee, 2015; Lee et al., 2014). Anxiety was significantly associated with smartphone addiction/use in 8 of the 9 reviewed studies. Bivariate correlations and multivariate beta coefficients were generally smaller than for depression, more typically around .20. These results were similar when only considering the more recent studies.

#### 6.3.3. Stress

Six studies examined stress symptoms (Augner and Hacker, 2012; Harwood et al., 2014; Jeong et al., 2016; Thomée et al., 2011; van Deursen et al., 2015; Wang et al., 2015). Each study used a different measure of stress, including the DASS, Perceived Stress Scale, Chronic Stress Inventory, a variation of the Brief Fear of Negative Evaluation Scale, items adapted from the Hassles Scale and Uplifts Scale, and a single-item stress measure. Statistically significant associations between problematic smartphone use and stress were found in 5 of the 6 studies reviewed. Effect sizes were in the $r$ =.20–.30 range. The majority of multivariate associations were significant, mostly with betas ranging from .10 to .30. Results were similar when considering only the more recent studies.

#### 6.3.4. Self-Esteem

Six studies examined self-esteem (Ehrenberg et al., 2008; Ha et al., 2008; Hong et al., 2012; Khang et al., 2013; Smetaniuk, 2014; Walsh et al., 2011). All but one of these studies used the Rosenberg Self-Esteem Scale; the remaining study (Ehrenberg et al., 2008) used the Coopersmith Self-Esteem Inventory. Statistically significant associations between lower self-esteem and greater problem smartphone use

were found in 5 of the 6 studies reviewed. Effect sizes ranged from $r$=−.10 to $r$=−.30. Statistical adjustment in regression models included several significant and several non-significant findings; betas were mostly from near zero to −.20. Results were very similar when only considering the more recent studies – however, bivariate relations were only examined in one study, finding $r$ of −.27.

## 7. Discussion

Our general findings suggest that problematic and general smartphone use commonly co-occur with the mental disorder constructs of depression, anxiety, and also with stress. We found depression severity to be consistently, significantly linked with smartphone addiction. Based on effect size conventions (Cohen, 1988), these relationships generally had at least medium bivariate effect sizes, though slightly lower on average when statistically controlling for other relevant variables. Anxiety severity was also consistently, significantly associated with problem smartphone use, with small effect sizes. Stress severity was fairly consistently associated with problem smartphone use, with small to medium effects. Self-esteem was not consistently associated with problem use; although bivariate effects were small to medium in size, they were much lower in absolute size in multivariate analyses.

The depression and anxiety constructs related to problem smartphone use are particularly noteworthy to discuss. In epidemiological studies, people with major depressive disorder are very likely to be diagnosed with anxiety disorders, and vice versa (Cummings et al., 2014; Lamers et al., 2011). Future research should test whether variance in smartphone addiction is more explained by depression or anxiety. Additionally, privacy issues with data on smartphones, and associated user anxiety (Elhai and Hall, 2016), should be further studied.

### 7.1. Explanations for psychopathology's relations with problematic smartphone use

The studies reviewed in our paper were predominantly correlational in design, thus making it difficult to infer cause from effect regarding the relationship between psychopathology and problem smartphone use. However, two papers used longitudinal designs to clarify causality (Lu et al., 2014; Thomée et al., 2011). Three prominent causal explanations have been discussed in the literature, discussed below.

First, placed within the larger context of research on the internet and technology's relations with psychopathology, there is some evidence that psychopathology, such as depression or anxiety, can cause technology addiction. For example, chronically stressed individuals are found to use online video gaming as a coping mechanism to relieve their stress (though not typically a successful stress relief strategy) (Snodgrass et al., 2014). Furthermore, depressed individuals use their mobile phones as a coping method to deal with their depressive, negative emotion (Kim et al., 2015a). Thus smartphone use could function as an experiential avoidance strategy to deflect aversive emotional content; however, experiential avoidance is ineffective toward this goal, and has adverse emotional consequences (Machell et al., 2015). In fact, the possibility that psychopathology can cause problem smartphone use fits with Billieux et al.'s (2015a) focus on the excessive reassurance seeking pathway toward addiction. Excessive reassurance seeking is a feature and maintenance factor of depression (Evraire and Dozois, 2011) and anxiety (Cougle et al., 2012; Rector et al., 2011), and can manifest through repeated, problematic use of phone checking behaviors (Billieux et al., 2015a).

Second, some evidence suggests that increased levels of technology use can cause the types of psychopathology discussed here. For example, in a longitudinal study of college students, Thomée et al. (2007) found that those categorized as heavy users of computers, social media and mobile phones report greater subsequent levels of prolonged stress, depression and sleep disturbance. Furthermore, in a community study of young adults, even after excluding participants with baseline mental health problems, high mobile phone use was associated with subsequent stress, sleep difficulties and depression at one-year follow-up (Thomée et al., 2011). Relatedly, excessive smartphone use at night, in particular, could keep one awake late, thus impairing sleep, and influencing stress and depression (Lemola et al., 2015). However, alternative explanations for why problem smartphone use can lead to these mental health problems include: a) blue light emitted from smartphones can interfere with sleep (Oh et al., 2015), and b) increasing work demands to stay digitally connected can cause stress and burnout (Derks and Bakker, 2014; Derks et al., 2012).

Third, other evidence suggests a bidirectional relationship, whereby problem smartphone use drives psychopathology, and psychopathology further drives problematic use (van den Eijnden et al., 2008; Yen et al., 2012). For example, a depressed individual may be driven to excessively use his/her smartphone to escape the negative emotion of depression. However, this excessive smartphone use consequently keeps the individual up late at night and thus elicits more depression, irritability and stress. Thus smartphone addiction can involve a vicious cycle with psychopathology (Kim et al., 2015a).

### 7.2. Limitations

As we indicated above, we only included correlational studies in our review of smartphone use/addiction with psychopathology. Of note, another type of design that has been used in this area is to separate research participants from their smartphones, and measure their resulting mental health status. Two studies of college students used this design, and measured anxiety and/or physiological response ratings after separation – compared to ratings from participants who were not separated from their phones (Cheever et al., 2014; Clayton et al., 2015). These studies found support for significant increases in anxiety upon being separated from one's smartphone. Cheever et al. (2014) found anxiety to gradually increase over time among excessive mobile device users. And Clayton et al. (2015) found anxiety, blood pressure and heart rate increases when placing a phone call to subjects' phones that were audible to the subjects, while being separated from the phone. Such a design can further clarify the real-world relationships between problematic smartphone use and psychopathology.

### 7.3. 3. Conclusions

In conclusion, we found most support for relationships between problematic smartphone use and both depression and anxiety severity. Mild support was found for stress and self-esteem constructs. Future research should expand from these psychopathology constructs to assess additional constructs related to problematic smartphone use.

## References

Alt, D., 2015. College students' academic motivation, media engagement and fear of missing out. Comput. Hum. Behav. 49, 111–119.
Augner, C., Hacker, G.W., 2012. Associations between problematic mobile phone use and psychological parameters in young adults. Int. J. Public Health 57, 437–441.
Baker, T.B., Piper, M.E., McCarthy, D.E., Majeskie, M.R., Fiore, M.C., 2004. Addiction motivation reformulated: an affective processing model of negative reinforcement. Psychol. Rev. 111, 33–51.
Bianchi, A., Phillips, J.G., 2005. Psychological predictors of problem mobile phone use. Cyber. Behav. 8, 39–51.
Bastian, H., Glasziou, P., Chalmers, I., 2010. Seventy-five trials and eleven systematic reviews a day: how will we ever keep up? PLoS Med. 7, e1000326.
Beranuy, M., Oberst, U., Carbonell, X., Chamarro, A., 2009. Problematic internet and mobile phone use and clinical symptoms in college students: The role of emotional intelligence. Comp. Human Behav. 25, 1182–1187.
Billieux, J., Van der Linden, M., Rochat, L., 2008. The role of impulsivity in actual and problematic use of the mobile phone. Appl. Cogn. Psychol. 22, 1195–1210.
Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D.J., Griffiths, M.D., 2015a. Can disordered mobile phone use be considered a behavioral addiction? An update on current evidence and a comprehensive model for future research. Curr. Addict. Rep.

2, 156–162.
Billieux, J., Philippot, P., Schmid, C., Maurage, P., De Mol, J., Van der Linden, M., 2015b. Is dysfunctional use of the mobile phone a behavioural addiction? Confronting symptom-based versus process-based approaches. Clin. Psychol. Psychother. 22, 460–468.
Cazzulino, F., Burke, R.V., Muller, V., Arbogast, H., Upperman, J.S., 2014. Cell phones and young drivers: a systematic review regarding the association between psychological factors and prevention. Traffic Inj. Prev. 15, 234–242.
Cheever, N.A., Rosen, L.D., Carrier, L.M., Chavez, A., 2014. Out of sight is not out of mind: the impact of restricting wireless mobile device use on anxiety levels among low, moderate and high users. Comput. Hum. Behav. 37, 290–297.
Cho, J., 2015. Roles of smartphone app use in improving social capital and reducing social isolation. Cyber. Behav. Soc. Netw. 18, 350–355.
Clayton, R.B., Leshner, G., Almond, A., 2015. The extended iSelf: the impact of iPhone separation on cognition, emotion, and physiology. J. Comput.-Mediat. Commun. 20, 119–135.
Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences 2nd ed.. Lawrence Erlbaum Associates, Hillside, New Jersey.
Cougle, J.R., Fitch, K.E., Fincham, F.D., Riccardi, C.J., Keough, M.E., Timpano, K.R., 2012. Excessive reassurance seeking and anxiety pathology: tests of incremental associations and directionality. J. Anxiety Disord. 26, 117–125.
Cummings, C.M., Caporino, N.E., Kendall, P.C., 2014. Comorbidity of anxiety and depression in children and adolescents: 20 years after. Psychol. Bull. 140, 816–845.
Demirci, K., Akgonul, M., Akpinar, A., 2015. Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students. J. Behav. Addict. 4, 85–92.
Derks, D., Bakker, A.B., 2014. Smartphone use, work-home interference, and burnout: a diary study on the role of recovery. Appl. Psychol. 63, 411–440.
Derks, D., ten Brummelhuis, L.L., Zecic, D., Bakker, A.B., 2012. Switching on and off ...: does smartphone use obstruct the possibility to engage in recovery activities? Eur. J. Work Organ. Psychol. 23, 80–90.
Ehrenberg, A., Juckes, S., White, K.M., Walsh, S.P., 2008. Personality and self-esteem as predictors of young people's technology use. Cyber. Behav. 11, 739–741.
van den Eijnden, R.J., Meerkerk, G.J., Vermulst, A.A., Spijkerman, R., Engels, R.C., 2008. Online communication, compulsive Internet use, and psychosocial well-being among adolescents: a longitudinal study. Dev. Psychol. 44, 655–665.
Elhai, J.D., Hall, B.J., 2016. Anxiety about internet hacking: results from a community sample. Comput. Hum. Behav. 54, 180–185.
Evraire, L.E., Dozois, D.J., 2011. An integrative model of excessive reassurance seeking and negative feedback seeking in the development and maintenance of depression. Clin. Psychol. Rev. 31, 1291–1303.
Frommer, D., 2011, June 6. History less: How the iPhone changed smartphones forever. Business Insider. http://www.businessinsider.com/iphone-android-smartphones-2011-6?op=1
Guzeller, C.O., Cosguner, T., 2012. Development of a problematic mobile phone use scale for Turkish adolescents. Cyber. Behav. Soc. Netw. 15, 205–211.
Ha, J.H., Chin, B., Park, D.H., Ryu, S.H., Yu, J., 2008. Characteristics of excessive cellular phone use in Korean adolescents. Cyber. Behav. 11, 783–784.
Harwood, J., Dooley, J.J., Scott, A.J., Joiner, R., 2014. Constantly connected: the effects of smart-devices on mental health. Comput. Hum. Behav. 34, 267–272.
Hoffner, C.A., Lee, S., 2015. Mobile phone use, emotion regulation, and well-being. Cyber. Behav. Soc. Netw. 18, 411–416.
Hong, F.-Y., Chiu, S.-I., Huang, D.-H., 2012. A model of the relationship between psychological characteristics, mobile phone addiction and use of mobile phones by Taiwanese university female students. Comput. Hum. Behav. 28, 2152–2159.
İNal, E.E., Demİrcİ, K., ÇetİntürK, A., Akgönül, M., Savaş, S., 2015. Effects of smartphone overuse on hand function, pinch strength, and the median nerve. Muscle Nerve 52, 183–188.
Jacobsen, W.C., Forste, R., 2011. The wired generation: academic and social outcomes of electronic media use among university students. Cyber. Behav. Soc. Netw. 14, 275–280.
Jeong, S.-H., Kim, H., Yum, J.-Y., Hwang, Y., 2016. What type of content are smartphone users addicted to?: sns vs. games. Comput. Hum. Behav. 54, 10–17.
Kardefelt-Winther, D., 2014. A conceptual and methodological critique of internet addiction research: towards a model of compensatory internet use. Comput. Hum. Behav. 31, 351–354.
Khang, H., Kim, J.K., Kim, Y., 2013. Self-traits and motivations as antecedents of digital media flow and addiction: the Internet, mobile phones, and video games. Comput. Hum. Behav. 29, 2416–2424.
Kim, D., Lee, Y., Lee, J., Nam, J.K., Chung, Y., 2014. Development of Korean Smartphone Addiction Proneness Scale for youth. PloS One 9, e97920.
Kim, J., Seo, M., David, P., 2015a. Alleviating depression only to become problematic mobile phone users: can face-to-face communication be the antidote? Comput. Hum. Behav. 51, 440–447.
Kim, R., Lee, K.J., Choi, Y.J., 2015b. Mobile phone overuse among elementary school students in Korea: factors associated with mobile phone use as a behavior addiction. J. Addict. Nurs. 26, 81–85.
Kiraly, O., Griffiths, M.D., Urban, R., Farkas, J., Kokonyei, G., Elekes, Z., Tamas, D., Demetrovics, Z., 2014. Problematic internet use and problematic online gaming are not the same: findings from a large nationally representative adolescent sample. Cyber. Behav. Soc. Netw. 17, 749–754.
Kruger, D.J., Djerf, J.M., 2016. High ringxiety: attachment anxiety predicts experiences of phantom cell phone ringing. Cyber. Behav. Soc. Netw. 19, 56–59.
Kuss, D., Griffiths, M.D., 2012. Internet gaming addiction: a systematic review of empirical research. Int. J. Ment. Health Addict. 10, 278-296..
Kuss, D., Griffiths, M., Karila, L., Billieux, J., 2014. Internet addiction: a systematic review of epidemiological research for the last decade. Curr. Pharm. Des. 20, 4026–4052.
Kwon, M., Kim, D.J., Cho, H., Yang, S., 2013a. The smartphone addiction scale: development and validation of a short version for adolescents. PLoS One 8, e83558.
Kwon, M., Lee, J.Y., Won, W.Y., Park, J.W., Min, J.A., Hahn, C., Gu, X., Choi, J.H., Kim, D.J., 2013b. Development and validation of a smartphone addiction scale (SAS). PloS One 8, e56936.
Lamers, F., van Oppen, P., Comijs, H.S., Smit, J.H., Spinhoven, P., van Bolkom, A.J., Nolen, W.A., Zitman, F.G., Beekman, A.T., Penninx, B.W., 2011. Comorbidity patterns of anxiety and depressive disorders in a large cohort study: the Netherlands Study of Depression and Anxiety (NESDA). J. Clin. Psychiatry 72, 341–348.
Lee, E.B., 2015. Too much information: heavy smartphone and Facebook utilization by African American young adults. J. Black Stud. 46, 44–61.
Lee, Y.-K., Chang, C.-T., Lin, Y., Cheng, Z.-H., 2014. The dark side of smartphone usage: psychological traits, compulsive behavior and technostress. Comput. Hum. Behav. 31, 373–383.
Lemola, S., Perkinson-Gloor, N., Brand, S., Dewald-Kaufmann, J.F., Grob, A., 2015. Adolescents' electronic media use at night, sleep disturbance, and depressive symptoms in the smartphone age. J. Youth Adolesc. 44, 405–418.
Lepp, A., Barkley, J.E., Karpinski, A.C., 2014. The relationship between cell phone use, academic performance, anxiety, and satisfaction with life in college students. Comput. Hum. Behav. 31, 343–350.
Lepp, A., Barkley, J.E., Sanders, G.J., Rebold, M., Gates, P., 2013. The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. Int. J. Behav. Nutr. Phys. Act. 10, 79.
Lopez-Fernandez, O., Honrubia-Serrano, L., Freixa-Blanxart, M., Gibson, W., 2014. Prevalence of problematic mobile phone use in British adolescents. Cyber. Behav. Soc. Netw. 17, 91–98.
Lu, X., Katoh, T., Chen, Z., Nagata, T., Kitamura, T., 2014. Text messaging: are dependency and excessive use discretely different for Japanese university students? Psychiatry Res 216, 255–262.
Lu, X., Watanabe, J., Liu, Q., Uji, M., Shono, M., Kitamura, T., 2011. Internet and mobile phone text-messaging dependency: factor structure and correlation with dysphoric mood among Japanese adults. Comput. Hum. Behav. 27, 1702–1709.
MacCallum, R.C., Zhang, S., Preacher, K.J., Rucker, D.D., 2002. On the practice of dichotomization of quantitative variables. Psychol. Methods 7, 19–40.
Machell, K.A., Goodman, F.R., Kashdan, T.B., 2015. Experiential avoidance and well-being: a daily diary analysis. Cogn. Emot. 29, 351–359.
Moher, D., Shamseer, L., Clarke, M., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., PRISMA-P Group, Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews 4, 2015.
Mok, J.Y., Choi, S.W., Kim, D.J., Choi, J.S., Lee, J., Ahn, H., Choi, E.J., Song, W.Y., 2014. Latent class analysis on internet and smartphone addiction in college students. Neuropsychiatr. Dis. Treat. 10, 817–828.
Morford, M. 2010, August 4. Oh my God you are so missing out. SF Gate. http://www.sfgate.com/entertainment/morford/article/Oh-my-God-you-are-so-missing-out-2536241.php
Oh, J.H., Yoo, H., Park, H.K., Do, Y.R., 2015. Analysis of circadian properties and healthy levels of blue light from smartphones at night. Sci. Rep. 5, 11325.
Oulasvirta, A., Rattenbury, T., Ma, L., Raita, E., 2012. Habits make smartphone use more pervasive. Pers. Ubiquitous Comput. 16, 105–114.
Pew Research Center, 2014, February 13. Emerging nations embrace internet, mobile technology. Pew Research Center. http://www.pewglobal.org/2014/02/13/emerging-nations-embrace-internet-mobile-technology/
Poushter, J., 2016, February 22. Smartphone ownership and internet usage continues to climb in emerging economies: but advanced economies still have higher rates of technology use. Pew Research Center. http://www.pewglobal.org/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/
Prabu, D., Kim, J.-H., Brickman, J.S., Ran, W., Curtis, C.M., 2015. Mobile phone distraction while studying. New Media Soc. 17, 1661–1679.
Przybylski, A.K., Murayama, K., DeHaan, C.R., Gladwell, V., 2013. Motivational, emotional, and behavioral correlates of fear of missing out. Comput. Hum. Behav. 29, 1841–1848.
Rebold, M.J., Sheehan, T., Dirlam, M., Maldonado, T., O'Donnell, D., 2016. The impact of cell phone texting on the amount of time spent exercising at different intensities. Comput. Hum. Behav. 55, 167–171.
Rector, N.A., Kamkar, K., Cassin, S.E., Ayearst, L.E., Laposa, J.M., 2011. Assessing excessive reassurance seeking in the anxiety disorders. J. Anxiety Disord. 25, 911–917.
Robinson, T.E., Berridge, K.C., 1993. The neural basis of drug craving: an incentive-sensitization theory of addiction. Brain Res. Rev. 18, 247–291.
Robinson, T.E., Berridge, K.C., 2000. The psychology and neurobiology of addiction: an incentive-sensitization view. Addiction 95, S91–S117.
Robinson, T.E., Berridge, K.C., 2001. Incentive-sensitization and addiction. Addiction 96, 103–114.
Robinson, T.E., Berridge, K.C., 2003. Addiction. Annu. Rev. Psychol. 54, 25–53.
Schulenberg, J., O'Malley, P.M., Bachman, J.G., Johnston, L.D., Crockett, L.J., Silbereisen, R.K., 2000. 'Spread your wings and fly': the course of well-being and substance use during the transition to young adulthood. In: Crockett, L.J., Silbereisen, R.K. (Eds.), Negotiating Adolescence in Times of Social Change. Cambridge University Press, New York, New York, 224–255.
Schwebel, D.C., Stavrinos, D., Byington, K.W., Davis, T., O'Neal, E.E., de Jong, D., 2012. Distraction and pedestrian safety: how talking on the phone, texting, and listening to music impact crossing the street. Accid. Anal. Prev. 45, 266–271.
Shan, Z., Deng, G., Li, J., Li, Y., Zhang, Y., Zhao, Q., 2013. Correlational analysis of neck/

shoulder pain and low back pain with the use of digital products, physical activity and psychological status among adolescents in Shanghai. PLoS One 8, e78109.
Shedler, J., Block, J., 1990. Adolescent drug use and psychological health: a longitudinal inquiry. Am. Psychol. 45, 612–630.
Shiffman, S., Gwaltney, C.J., Balabanis, M.H., Liu, K.S., Paty, J.A., Kassel, J.D., Hickcox, M., Gnys, M., 2002. Immediate antecedents of cigarette smoking: an analysis from ecological momentary assessment. J. Abnorm. Psychol. 111, 531–545.
Smetaniuk, P., 2014. A preliminary investigation into the prevalence and prediction of problematic cell phone use. J. Behav. Addict. 3, 41–53.
Smith, A., Page, D., 2015, April 1. U.S. smartphone use in 2015. PewResearch Internet Project. Pew Research. http://www.pewinternet.org/files/2015/03/PI_Smartphones_0401151.pdf
Snodgrass, J.G., Lacy, M.G., Dengah, H.J.F., Eisenhauer, S., Batchelder, G., Cookson, R.J., 2014. A vacation from your mind: problematic online gaming is a stress response. Comput. Hum. Behav. 38, 248–260.
Song, I., Larose, R., Eastin, M.S., Lin, C.A., 2004. Internet gratifications and Internet addiction: on the uses and abuses of new media. Cyber. Behav. Soc. Netw. 7, 384–394.
Soror, A.A., Hammer, B.I., Steelman, Z.R., Davis, F.D., Limayem, M.M., 2015. Good habits gone bad: explaining negative consequences associated with the use of mobile phones from a dual-systems perspective. Inf. Syst. J. 25, 403–427.
Thomée, S., Härenstam, A., Hagberg, M., 2011. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults: a prospective cohort study. BMC Public Health 11, 66.
Thomée, S., Eklöf, M., Gustafsson, E., Nilsson, R., Hagberg, M., 2007. Prevalence of perceived stress, symptoms of depression and sleep disturbances in relation to information and communication technology (ICT) use among young adults: an explorative prospective study. Comput. Hum. Behav. 23, 1300–1321.
Thompson, L.L., Rivara, F.P., Ayyagari, R.C., Ebel, B.E., 2013. Impact of social and technological distraction on pedestrian crossing behaviour: an observational study. Inj. Prev. 19, 232–237.
van Deursen, A.J.A.M., Bolle, C.L., Hegner, S.M., Kommers, P.A.M., 2015. Modeling habitual and addictive smartphone behavior. Comput. Hum. Behav. 45, 411–420.
Walsh, S., White, K.M., McD Young, R., 2010. Needing to connect: the effect of self and others on young people's involvement with their mobile phones. Aust. J. Psychol. 62, 194–203.
Walsh, S., White, K.M., Cox, S., Young, R.M., 2011. Keeping in constant touch: the predictors of young Australians' mobile phone involvement. Comput. Hum. Behav. 27, 333–342.
Wang, J.-L., Wang, H.-Z., Gaskin, J., Wang, L.-H., 2015. The role of stress and motivation in problematic smartphone use among college students. Comput. Hum. Behav. 53, 181–188.
Widyanto, L., Griffiths, M., 2006. 'Internet addiction': a critical review. Int. J. Ment. Health Addict. 4, 31–51.
Wise, R.A., Koob, G.F., 2014. The development and maintenance of drug addiction. Neuropsychopharmacology 39, 254–262.
Xie, Y., Szeto, G.P., Dai, J., Madeleine, P., 2016. A comparison of muscle activity in using touchscreen smartphone among young people with and without chronic neck-shoulder pain. Ergonomics 59, 61–72.
Yen, C.F., Tang, T.C., Yen, J.Y., Lin, H.C., Huang, C.F., Liu, S.C., Ko, C.H., 2009. Symptoms of problematic cellular phone use, functional impairment and its association with depression among adolescents in Southern Taiwan. J. Adolesc. 32, 863–873.
Yen, J.Y., Cheng-Fang, Y., Chen, C.S., Chang, Y.H., Yeh, Y.C., Ko, C.H., 2012. The bidirectional interactions between addiction, behaviour approach and behaviour inhibition systems among adolescents in a prospective study. Psychiatry Res. 200, 588–592.