

Problematic smartphone use, nature connectedness, and anxiety

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Background: Smartphone use has increased greatly at a time when concerns about society's disconnection from nature have also markedly increased. Recent research has also indicated that smartphone use can be problematic for a small minority of individuals. *Methods:* In this study, associations between problematic smartphone use (PSU), nature connectedness, and anxiety were investigated using a cross-sectional design ($n = 244$). *Results:* Associations between PSU and both nature connectedness and anxiety were confirmed. Receiver operating characteristic (ROC) curves were used to identify threshold values on the Problematic Smartphone Use Scale (PSUS) at which strong associations with anxiety and nature connectedness occur. The area under the curve was calculated and positive likelihood ratios used as a diagnostic parameter to identify optimal cut-off for PSU. These provided good diagnostic ability for nature connectedness, but poor and non-significant results for anxiety. ROC analysis showed the optimal PSUS threshold for high nature connectedness to be 15.5 (sensitivity: 58.3%; specificity: 78.6%) in response to an LR+ of 2.88. *Conclusions:* The results demonstrate the potential utility for the PSUS as a diagnostic tool, with a level of smartphone use that users may perceive as non-problematic being a significant cut-off in terms of achieving beneficial levels of nature connectedness. Implications of these findings are discussed.

Keywords: nature connectedness, smartphones, addiction, anxiety

INTRODUCTION

The UK is now a “smartphone society” with 68% of adults owning a smartphone (Poushter, 2016). Uncontrolled and excessive use of a smartphone can give rise to social, behavioral, and affective problems (Choliz, 2010), which in turn can lead to problematic smartphone use (PSU) among a minority of individuals. The prevalence of PSU varies between populations, but has been reported at 10% among British adolescents (Lopez-Fernandez, Honrubia-Serrano, Freixa-Blanxart, & Gibson, 2014) and 20% among Spanish adolescents (Sánchez-Martínez & Otero, 2009). Reported symptoms of PSU include excessive use of the device, interference with educational, occupational and/or personal activities, a gradual increase in use to obtain the same level of prior satisfaction in relation to mood states, emotional alterations, and/or withdrawal symptoms when use is impeded (Billieux, Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015).

These addiction-forming symptoms have led some researchers to classify PSU as a potential behavioral addiction (Bianchi & Phillips, 2005; Lopez-Fernandez, Kuss, Griffiths, & Billieux, 2015) showing symptoms of addiction in adolescents (e.g., lack of control and cravings) and negative mood states, such as anxiety (Kim, Lee, & Choi, 2015). Although technology and smartphones are often acknowledged as potential causes of a growing human disconnection with nature, there is little direct research evidence (Fletcher, 2017), with few,

if any, studies specifically examining nature connectedness and smartphone use. This is important as human relationships with nature bring mental well-being benefits at a time of huge demand on health services (Richardson et al., 2017), and pro-environmental benefits at a time of rapid decline in the state of the natural environment which sustains civilization (Ceballos, Ehrlich, & Dirzo, 2017). This is the first study to examine the relationship between PSU and nature connectedness, exploring PSU thresholds for higher nature connectedness and anxiety.

Smartphones have become a necessity for many people that for some individuals can lead to dependent use. Much research has focused on the psychological aspects of smartphone use (Billieux et al., 2015) and there is empirical evidence showing associations between anxiety and PSU (Tavakolizadeh, Atarodi, Ahmadpour, & Pourghesiar, 2014; Kim et al., 2015). Cheever, Rosen, Carrier, and Chavez (2014) examined anxiety among American college students when wireless mobile devices (WMDs), including smartphones, were not available. The results showed that heavy and moderate WMD users felt significantly more anxious over time. The researchers concluded that dependency upon WMDs, mediated by an unhealthy connection to their constant use, may lead to increased anxiety when the device

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was absent. Overall, these studies show that overuse of smartphones in some individuals may be associated with a form of psychological dependency, with a prominent feature being anxiety.

The pathways model describes the various pathways leading to problematic phone use (Billieux, 2012; Billieux et al., 2015). The first pathway (the *impulsive pathway*) relates to mobile phone use that is mainly driven by maladaptive emotion regulation and/or poor self-control. The second pathway (the *relationship maintenance pathway*) relates to excessive mobile phone use to obtain reassurance in affective relationships. These individuals are generally characterized by a high neuroticism and low self-esteem. The third pathway (the *extraversion pathway*) relates to people who are susceptible to excessive mobile phone use, because they are sociable and hold an elevated desire to communicate with peers to establish new relationships. Finally, there is a fourth *cyber addiction* pathway.

“Nature connectedness” is a psychological construct that reflects people’s “connection with nature” (Mayer & Frantz, 2004). It is associated with a range of well-being benefits (for a recent review, see Richardson et al., 2017) and pro-environmental behaviors (e.g., Frantz & Mayer, 2014). In recent years, research studies into topics related to nature connectedness have grown markedly (Ives et al., 2017). A proportion of this research has investigated the mental well-being benefits of nature connectedness. These include life satisfaction (Mayer & Frantz, 2004), meaningfulness (Cervinka, Röderer, & Hefler, 2012; Howell, Passmore, & Buro, 2013; Mayer, Frantz, Bruhlman-Senecal, & Dolliver, 2009), vitality (Capaldi, Dopko, & Zelenski, 2014), happiness (Nisbet, Zelenski, & Murphy, 2011), higher self-esteem (Swami, von Nordheim, & Barron, 2016), and mindfulness (Howell, Dopko, Passmore, & Buro, 2011). These relationships are of a similar magnitude to those found between well-being and variables, such as personal income, marriage, and education, whose associations with well-being are well established (Capaldi et al., 2014; Mayer & Frantz, 2004). Nature connectedness has also been found to mediate the relationship between happiness and health (Richardson, Cormack, et al., 2016) and bring about increased visits to green spaces (Lin, Fuller, Bush, Gaston, & Shanahan, 2014), where the wider benefits of exposure to nature, such as balanced emotional regulation (Richardson, McEwan, et al., 2016) and restoration can be realized. Therefore, during increased demands on health care systems and environmental issues that pose a threat to civilization (Ceballos et al., 2017), people’s disconnection from nature is now acknowledged as a societal issue through research and government policy (HM Government, 2018).

More broadly, the wider relationship between people, technology, and nature should be considered. Technological advances have seen people settle, farm, and then leave villages for an industrial life in urban environments. In an analysis of works of popular culture throughout the twentieth century, Kesebir and Kesebir (2017) identified a cultural shift away from nature with a sharp decline in nature references from the 1950s to 2000. Two arguments that are often put forward to explain the growing disconnection from nature are urbanization and technology. Kesebir and Kesebir argue that rates of increasing urbanization do not mirror the decline of

nature words, yet the dawns of new technology do (from television in the 1950s to video games in the 1980s). It is clear that technology shapes and defines people more and more (Taylor, 2010), because technology has allowed people to master nature to reduce the impact of disease and hunger, such that the demands of technology dominate culture, morality, and pose a threat to the ecology that sustains human life (Schmidt & Marratto, 2008). Vanderburg (2000) argued that there are cultural phases, and that connectedness to technology comes between people and nature.

The widespread use of smartphones may be another new dawn of disconnection, a technology that through uses such as social media, reflects and ultimately shapes culture itself (Kesebir & Kesebir, 2017), more rapidly perhaps than seen in the past. However, connecting people with nature cannot be about demonizing technology or going back to (non-existent) halcyon days. A connectedness with nature must be part of a modern, increasingly urban lifestyle and therefore new technology must be embraced to engage people with nature. Indeed, there is emerging evidence that technology can be used to increase nature connectedness through immersive technologies (Soliman, Peetz, & Davydenko, 2017). The difficulty is in creating a technological culture that is also more connected to the natural world (Schmidt & Marratto, 2008). Returning to specifics of smartphone technology and nature connectedness, there is often public debate about technology and people’s relationship with nature and virtual nature (Stinson, 2017). Focused research studies concerning the impact of technology on the construct of nature connectedness is surprisingly limited. An initial insight into such a relationship is needed to kick-start further research and thinking into how smartphone technologies can play a positive, rounded role in a nature-connected society.

Study rationale and aims

Research has shown that for some individuals, PSU is associated with various negative psychological states including anxiety and it is hypothesized to be associated with a lower connectedness with nature. There are no prior studies investigating the associations between nature connectedness and smartphone use. Consequently, this study will begin to fill this gap in research knowledge. Furthermore, when implementing guidelines or interventions to achieve outcomes, such as reduced smartphone-induced anxiety or higher nature connectedness, evidence-based thresholds are required.

This study aims to establish if threshold levels can be established for anxiety and nature connectedness using a robustly calculated cut-off score on the Problematic Smartphone Use Scale (PSUS; Hussain, Griffiths, & Sheffield, 2017). Having an indication of what a concerning level of PSU is will help guide the work of those attempting to reduce smartphone addiction and anxiety, or improve nature connectedness. The study therefore had three aims. These are to identify (a) the relationship between nature connectedness and PSU; (b) thresholds of PSU, identifying where higher levels of nature connectedness are more likely to occur; and (c) thresholds of PSU, identifying where higher levels of anxiety are more likely to occur.

METHODS

Participants

A total of 310 smartphone users (mean age = 29.72 years, $SD = 12.16$) participated in the study. Some data were missing from the surveys due to incomplete responses. Therefore, statistical analysis was performed on the 244 fully completed surveys. There were 90 males (36.9%) and 149 females (61.1%), with five participants (2.0%) choosing not to disclose their gender. Most of the participants were residents of the UK ($n = 202$, 82.8%), followed by the USA ($n = 12$, 4.9%), Australia ($n = 4$, 1.6%), and Canada ($n = 5$, 2.0%). The remaining 6.3% of participants ($n = 25$) were residents of other countries. The ethnicity of the sample was varied with the sample comprising of White ($n = 199$, 81.6%), BAME ($n = 37$, 15.2%), and 3.3% ($n = 8$) chose the "other" option when describing their ethnicity.

Procedure

An Internet-posted message inviting smartphone users to participate in the study was placed in the off-topic and general discussion forums of various well-known smartphone, social news, and online gaming websites. Internet-posted messages were also posted on social networking accounts. Furthermore, students at a large UK University were also informed by study recruitment announcements at the beginning of lectures. The online recruitment posting informed all participants about the purpose of the study and contained an online link to the online survey with a participant information page followed by clear instructions on how to complete the survey.

Measures

An online survey was used comprising three psychological instruments assessing state-trait anxiety, PSU, and nature connectedness. In addition, questions regarding demographic make-up of participants, smartphone usage time, selfie-taking frequency, and nature photography were collected.

The six-item Spielberger State-Trait Anxiety Inventory (STAI) – short form (Marteau & Bekker, 1992) was used to assess state-trait anxiety. This scale comprises statements assessed on a 4-point Likert scale (where 1 = not at all, 2 = somewhat, 3 = moderately, and 4 = very much). Example items include: "I feel calm," "I am tensed," and "I am worried." Marteau and Bekker (1992) reported acceptable reliability and validity for the STAI – short form. Furthermore, when compared with the full form of the STAI, the six-item version offers a briefer and acceptable scale for participants (Marteau & Bekker, 1992). A threshold of 40 has been suggested to detect clinically significant symptoms for the S-anxiety version of the scale (Julian, 2011), which equates to a level of 12 on the short form. This compares with norms of 9.1 (Taylor & Deane, 2002), or between 9.6 and 10.8 (Knight, Waal-Manning, & Spears, 1983). In this study, the internal consistency of the STAI was good (Cronbach's $\alpha = .85$).

The nine-item PSUS (Hussain et al., 2017) was used to assess PSU. Example items include: "I am preoccupied with

my smartphone," "I use my smartphone to escape or relieve a negative mood," "I have made unsuccessful attempts to control my smartphone use," and "I have spent increasing amounts of time on my smartphone." Participants rated all items on a 5-point Likert scale (where 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree). Scores range from 9 to 45. Hussain et al. (2017) have stated that for research purposes only, it may be possible to classify disordered users and non-disordered users by considering only those users who obtain a minimum of 36 out of 45 on the scale. In this study, the internal consistency of the PSUS was high (Cronbach's $\alpha = .86$).

The six-item short form Nature Relatedness Scale (NR-6; Nisbet & Zelenski, 2013) was used to assess participants' connectedness to nature. The scale comprises items that are scored on a 5-point Likert scale (where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). Example items include: "I take notice of wildlife wherever I am," "I always think about how my actions affect the environment," and "my relationship to nature is an important part of who I am." To facilitate ROC threshold analysis, the total score for the six items was used, rather than the mean figure derived by dividing the total by 6. Higher scores on the NR-6 indicated stronger connectedness to nature, with a community norm being a total score of 20.6 (Nisbet & Zelenski, 2013). In this study, the internal consistency of the NR-6 was high (Cronbach's $\alpha = .89$).

Statistical analyses

First, descriptive statistics regarding general smartphone use were calculated. This was followed by correlational analysis. To explore phone use and nature connectedness in more detail, multiple regression was used. Receiver operating characteristic (ROC) curves were used to identify the PSU threshold scores at which a user would be more likely to be better connected to nature (NR-6 greater than 25) and higher anxiety (STAI greater than 13). A ROC curve compares a true positive (sensitivity) with a true negative (specificity) of an outcome (Florkowski, 2008). This technique is often used in medical settings to identify thresholds of successful diagnostic tests (Zhang & Huang, 2005). The area under the curve (AUC) was used to examine the predictive accuracy of using the PSUS as an indicator of nature connectedness and anxiety (Florkowski, 2008), with a score of 0.5 or below indicating a chance result. AUC can be classified as less accurate (0.5–0.7), moderately accurate (0.7–0.9), highly accurate (0.9–1.0), or have perfect discrimination at 1.0 (Demura, Kasuga, Sato, Sato, & Shin, 2013). The thresholds that gave the highest probability of classifying a true positive and minimized the risk of a false negative were identified using a method based on calculating the lowest square of the distance between point (0, 1) of the ROC space and the point on the ROC curve (Hajian-Tilaki, 2013). Positive likelihood ratios (LR+) were calculated to indicate predictive utility and to confirm the optimal cut-off. A score of 1 indicates no predictive utility, whereas a greater value represents better predictive utility (Yuan et al., 2017).

Ethics

The research was approved by the research team's university Research Ethics Committee and adhered to the British Psychological Society ethical guidelines and the 1975 Helsinki Declaration. All participants were informed about the study and all provided informed consent.

RESULTS

The mean age of the sample was 29.8 years ($SD = 11.9$) with a mean average of 179.6 min daily smartphone use ($SD = 109.1$). The mean number of selfies a week was 4.51 ($SD = 13.1$) and the mean number of nature photos a week was 4.4 ($SD = 7.9$). The mean (and standard deviation) scores were also calculated for each of the scales: anxiety ($M = 12.02$, $SD = 3.71$), PSU ($M = 21.25$, $SD = 6.95$), and nature connectedness ($M = 21.39$, $SD = 5.49$).

Bivariate correlations demonstrated that PSU was positively related to anxiety, time spent on phone, and number of selfies taken. PSU was negatively related to nature connectedness and age. Nature connectedness was positively related to age and nature pictures taken per week, and negatively related to selfie-taking and smartphone usage times (Table 1).

The relationship between nature connectedness, PSU scores, time spent per day on smartphones, and selfie-taking was further examined using regression analysis. Age was included as a known predictor in a first block. Collinearity issues were checked using variance inflation factor values, which were all below 10 and multicollinearity was not a concern. Using the enter method for the multiple regression, it was found that the predictor variables explained a significant amount of variance in nature connectedness [$R^2 = .29$; $\Delta R^2 = .11$, $F(4, 238) = 9.55$, $p < .01$]. The analysis showed that age [$\beta = 0.27$, $t(244) = 4.29$, $p < .001$] and taking nature pictures [$\beta = 0.24$, $t(244) = 4.32$, $p < .01$] were significant positive predictors of nature connectedness. Selfie-taking [$\beta = -0.21$, $t(244) = -3.70$, $p < .01$] and time spent daily on smartphones [$\beta = -0.14$, $t(244) = -2.16$, $p = .03$] were significant negative predictors of nature. PSU was not a significant predictor ($p = .56$).

Given the association between PSUS and both nature connectedness and anxiety, further analysis was conducted to identify how the measure of PSUS might perform as a threshold indicator for high levels of nature connectedness and anxiety. The starting levels of NR-6 and STAI were

selected based upon the 75th percentile within the sample; therefore, the level for NR-6 was based around maximizing AUC around the level of 26, which compares with a community normative value of 21. Data from Richardson, Cormack, et al. (2016) show that those with a nature connectedness score in the upper quartile are significantly happier, healthier, and report significantly more pro-conservation behaviors. The 75th percentile for STAI was 14, however as there is existing guidance on what constitutes a high level of STAI, namely that clinically significant symptoms equate to a level of 12, analysis began at that level.

ROC curves showing the range of sensitivity and specificity of PSU as an indicator of nature connectedness and anxiety were performed (Figure 1). The threshold score of PSU that maximized AUC and sensitivity, while minimizing 1-specificity, was calculated along with LR+ and the full results are presented in Table 2. LR+ demonstrated that the optimal PSUS threshold for a high nature connectedness level of 25 was 15.5. A score of 25 on the NR-6 was 0.69 of standard deviations above the mean, close to the 0.67 figure

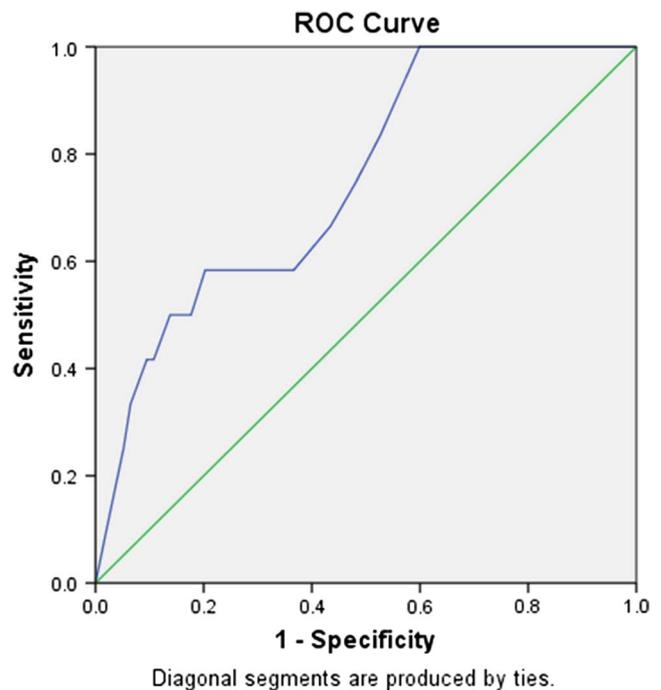


Figure 1. ROC curve showing the range of sensitivity and specificity of PSUS in relation to NR-6

Table 1. Pearson's correlations between Smartphone Problematic Use Scale scores and other variables ($n = 244$)

	Age	Daily phone use (min)	Selfies/week	Nature photos/week	STAI	PSUS	NR-6
Age	1	-0.364**	-0.211**	0.195**	-0.184**	-0.332**	0.420**
Daily phone use (min)		1	0.235**	0.034	0.120	0.416**	-0.290**
Selfies/week			1	0.073	0.089	0.265**	-0.294**
Nature photos/week				1	-0.069	-0.039	0.276**
STAI					1	0.305**	-0.067
PSUS						1	-0.248**
NR-6							1

Note. STAI: State Trait Anxiety Inventory; PSUS: Problematic Smartphone Use Scale; NRS-6: (six-item) Nature Relatedness Scale. ** $p < .01$.

Table 2. PSU threshold, sensitivity, specificity, AUC, standard error, and 95% confidence interval (CI) for nature connectedness and anxiety outcomes ($n = 244$)

Outcome	Cut-off score	PSUS threshold	Sensitivity	Specificity	LR+	AUC	95% CI	SE	Sig.
Nature connectedness	24	22.5	0.667	0.466	1.250	0.459	0.319–0.599	0.071	0.633
	25	15.5	0.583	0.797	2.879	0.749	0.621–0.876	0.065	0.004
	26	17.5	0.750	0.733	2.806	0.731	0.590–0.872	0.072	0.008
Anxiety	12	21.5	0.464	0.500	0.929	0.436	0.326–0.546	0.056	0.270
	13	21.5	0.636	0.518	1.320	0.533	0.416–0.650	0.060	0.613
	14	21.5	0.481	0.502	0.967	0.444	0.335–0.553	0.055	0.344
	15	24.5	0.455	0.293	0.643	0.284	0.178–0.389	0.054	0.001

Note. PSUS: Problematic Smartphone Use Scale; AUC: area under the curve; SE: standard error.

that covers the interquartile range within a distribution. ROC analysis for anxiety was non-significant.

DISCUSSION

This study explored the relationship between PSU, nature connectedness, and smartphone-associated anxiety. As predicted, PSU was negatively associated with nature connectedness, with selfie-taking and phone use emerging as predictors of decreased connectedness with nature. ROC analysis demonstrated that the PSUS provided good diagnostic ability for high nature connectedness, and that a score below 16 was the optimal PSUS threshold for high levels of nature relatedness. However, despite the predicted significance association between PSUS and anxiety, the PSUS was not found to have diagnostic ability for high levels of anxiety.

This study demonstrated an association between PSU and nature connectedness. However, as a cross-sectional study, the type of relationship remains unknown. For example, it could potentially be that interventions for increasing nature connectedness (e.g., Richardson, Cormack, et al., 2016) may provide a solution by lowering PSU. Alternatively, higher problematic smartphone has a negative impact on nature connectedness, with resulting negative effects on well-being and pro-environmental behaviors. The results of this study demonstrate that there is a need to examine these relationships further, and confirms that people’s relationship with technology matters.

Once the relationship is better understood, the results of the ROC analysis are positive. They demonstrate that the PSUS has diagnostic ability and there is potential to identify the lower levels of problematic smartphone needed for a higher connectedness with nature, which is emerging as a societal objective owing to the benefits to well-being and pro-environmental behaviors. Examining the results in more detail, a 25th percentile PSUS score was the threshold for a 75th percentile nature relatedness level associated with benefits for health, happiness, and pro-conservation behaviors. Examining the PSUS and response options, a score of 16 is very low, indicating that a level of smartphone use that users may perceive as non-problematic, is a significant cut-off in terms of its relationship to nature connectedness. Indeed, 75% of the study participants had a PSUS score above 16. However, this is not surprising given the large differences in smartphone use between those scoring upper

or lower quartile in nature relatedness. This demonstrated a difference in time spent daily using the smartphone as 221 min versus 140 min a day, with mean selfie-taking at one photograph per week, compared with nine, respectively. It is interesting to note that the PSUS threshold for higher NR-6 broadly matches the profile on these scales of those aged 50 years and over. Clearly, technologies and culture are always changing, such that there will be differences between generations, but the findings presented here emphasize the important need for longitudinal research to understand how people’s combined relationship with technology and nature is progressing.

Looking more closely at nature connectedness and smartphone use, there were significant negative associations with time spent daily using a smartphone, selfie-taking, and PSU. Regression analysis demonstrated that frequency of selfie-taking was the strongest predictor of lower nature connectedness, being significant alongside the known predictor of age. However, it should be noted that the selfie-taking data were significantly skewed by some more obsessive users. This compares with the frequency of taking nature photos, which was a significant predictor of increased nature connectedness. Time spent using smartphones everyday was a marginally non-significant predictor of lower nature connectedness. These results provide the first data on the relationship between the use of smartphone technology and people’s connectedness with nature. The regression analysis suggests that the amount and type of use (e.g., taking selfies vs. pictures of nature) is important and there is a need to understand the individual traits that lead to such types of use. However, the more robust and reliable data were provided by the PSUS.

Selfie-taking is a good example of how technology shapes and defines human behaviors (Murray, 2015), ultimately impacting on changes in culture over time as indicated by the associations between age, PSU, anxiety, and nature connectedness. Selfies are seen as an effective self-presentation tool and reflect individuals’ personalities and ideal self-concept (Shin, Kim, Im, & Chong, 2017). When considering the traits underlying selfie-taking, narcissism has been associated with taking more selfies (Sorokowski et al., 2015). Perhaps the explanation of the negative relationship of selfie-taking to nature connectedness, lies in increased self-interest and self-admiration, in contrast to traits of openness and conscious self-reflection, which are more likely to provide an understanding of a shared place in the natural world and increased connectedness to nature (Richardson & Sheffield, 2015).

Looking at the PSUS data, the results of this study suggest that increased time spent using a smartphone each day and selfie-taking are associated with problematic use. These results support the findings of previous studies (e.g., Thomée, Härenstam, & Hagberg, 2011). Anxiety was also positively correlated with PSU supporting past research (e.g., Cheever et al., 2014). However, unlike previous research (e.g., Lepp, Barkley, & Karpinski, 2014), time spent using a smartphone each day was not positively related to anxiety. This shows the value in the PSUS for identifying associations with potential outcomes, such as anxiety, although the ROC analysis demonstrated the PSUS had poor diagnostic utility concerning this relationship.

This study is not without its limitations. First, the unbalanced ratio of female to male participants. Second, the results were based on self-report measures, which can have an impact due to bias effects (e.g., social desirability and memory recall). Third, this study used a cross-sectional design; thus, no causality can be inferred. Future research should seek to examine the impact of changes in smartphone use on nature connectedness over time. It would also be beneficial to gather objective data on actual smartphone usage, first for the confidence in results, but also to study a broad range of other factors that influence smartphone-using behavior.

Smartphones have many features that make them attractive to users and make them a technology perhaps more impactful than television and video games, activities that have been associated with the decline of nature in popular culture (Kesebir & Kesebir, 2017). Smartphones provide autonomy, enhanced communication, and a type of extension to interpersonal relationship (by the use of SNS applications, blogs, etc.). Smartphones play a big part in many peoples' daily life and reflect and shape people's attitudes, behavior, and culture. The impact of smartphones on both well-being and people's connectedness with nature should further be researched. Given the low smartphone usage threshold required for high nature connectedness, intervention programs to help improve well-being and prevent problematic use of smartphones could be an option, and there is an indication that these programs could be based on developing a greater connectedness to nature.

Considering elements of the pathways model (Billieux, 2012), the impulsive pathway to smartphone addiction includes maladaptive emotion regulation and nature exposure brought about by connection is known to bring balance to the emotional regulation system (Richardson, McEwan, et al., 2016). Furthermore, the relationship maintenance pathway involves low levels of self-esteem and research has shown that nature connectedness is related to more positive self-perception (Swami et al., 2016). Nature connectedness-based interventions should be based on the pathways to nature connectedness, namely contact, emotion, meaning, compassion, and beauty (Lumber, Richardson, & Sheffield, 2017).

Montag et al. (2015) observed that participants who reported using wristwatches and alarm clocks used their smartphones significantly less. However, as smartphone functionality replaces other devices, it is likely the function and uses of the smartphone need to better structure everyday activity to include nature. This links to the need to identify

how nature can break the cycle of smartphone use and be brought into everyday life more generally, because research has shown doing so increases nature connectedness and mental well-being (Richardson, Cormack, et al., 2016; Richardson & Sheffield, 2017). Ultimately, smartphone use could automatically be detected, with models based on app use being able to identify users with problematic usage with good accuracy (Shin & Dey, 2013).

Given the cross-sectional nature of the research, the practical implications of the study take the field in one of two directions. Either decreasing smartphone use to far below current perceptions of a problematic level in order to increase connectedness with nature in order to decrease, or increasing connectedness with nature to decrease smartphone use. Given the research related to both topics, combined programs that decrease smartphone use and reconnect people with nature are therefore recommended for further research. However, this must be pragmatically conducted within the context of urban and technological living, so that smartphones are not demonized. Rather there is a need to build them into a more balanced and nature-connected lifestyle where new technology is also used to engage people with nature. For example, the findings of the present study suggest using smartphones for nature-related activities such as nature photography.

CONCLUSIONS

In summary, the widespread use of smartphones and their Internet-based technologies is the dawn of another new technology that shapes and defines day-to-day human behavior. Technology potentially reduces our connectedness with nature, with costs for the well-being of people and the environment that sustains us. The results demonstrated a number of directions for further research related to decreasing smartphone use and increasing nature connectedness. A greater connectedness with nature may provide a break from smartphone usage and potentially be used to overcome the different pathways to smartphone addiction, but a connectedness with nature should not be simply framed as an antidote. The emerging evidence is that nature connectedness is a key part of a healthy life and planet. However, the present findings showed that a level of smartphone use that users may perceive as non-problematic is a significant cut-off in terms of its relationship to levels of nature connectedness beneficial for mental well-being.

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Authors' contribution: MR, ZH, and MDG: manuscript writing, analysis, and interpretation of data. MR and ZH: study concept and design and statistical analysis. ZH: study supervision, data access, and integrity.

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