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Smartphone connectivity stress across generations: Validation of a brief scale for adolescents and adults

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ABSTRACT

Research into problematic smartphone use is growing as people are increasingly dependent on technological connections – a situation highlighted during the COVID-19 pandemic. However, current research has been limited by measurement validity issues and a lack of construct clarity. In response, this study developed and validated the Smartphone Connectivity Stress Scale (SCSS) for adolescents and adults. An online survey included an item pool, based on previous research and existing scales, as well as several psychosocial measures ($N = 814$; aged 14–80 years; 59% female). Iterative exploratory factor analyses, classical test theory and item response theory (IRT) analyses produced a unidimensional six-item scale of smartphone connectivity stress – from a perceived obligation to be constantly connected with others. Two-week test-retest reliability was assessed through a follow up survey ($n = 190$). SCSS factor structure and reliability were strong for adolescents (aged 14–18) and adults (aged 19–80). The SCSS demonstrated good internal consistency ($\alpha = 0.87$, $\omega_t = 0.91$); test-retest reliability, $r = 0.82$; and all items captured significant information across the latent trait. The SCSS demonstrated no differential item functioning by sex, age, ethnicity or urban/rural residence. The SCSS was positively correlated ($ps < .001$) with anxious attachment style and psychopathology symptoms (stress, anxiety, depression, suicidality). This is the first measure of smartphone connectivity stress and included valuable IRT analyses. The brief public domain SCSS provides reliable measurement, with reduced error, of a validated construct, and is suitable for use with adolescents and adults.

1. Introduction

Smartphones have become an indispensable part of daily life. The widespread adoption of smartphone technology is largely due to the many benefits and opportunities they offer, including the crucial facilitation of social connections during the COVID-19 pandemic (Van Bavel et al., 2020). However, extensive smartphone use has also brought a range of adverse behaviors and consequences. These include smartphone use in dangerous or prohibited situations (e.g., when driving), excessive use, and negative affect when separated from the device (De-Sola Gutiérrez, Rodríguez de Fonseca, & Rubio, 2016). This study investigated another consequence of modern-day smartphone use — stress from the perceived obligation to remain constantly connected with others, with emphasis on validating a measure of smartphone connectivity stress.

1.1. Current measures of problematic phone use

Past researchers have produced several scales attempting to operationally define and measure problematic mobile/smartphone use. We identified 11 scale validation studies on related constructs. Most scales assessed a similar psychological construct, namely one's dependence on their mobile device through addiction-like symptoms, such as excessive use, abstinence syndrome, and difficulty controlling the amount of time spent using their device (Bianchi & Phillips, 2005; Chóliz, 2012; Kwon et al., 2013; Walsh, White, & Young, 2010; Yen et al., 2009). Some measures focus on specific smartphone behaviors, such as text-messaging (Igarashi, Motoyoshi, Takai, & Yoshida, 2008; Rutland, Sheets, & Young, 2007), but still exist within an addiction paradigm. Only a few measures used alternative models in explaining problematic mobile/smartphone use, such as insecure attachment (Trub & Barbot, 2016), impulsivity

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(Billieux, Van Der Linden, & Rochat, 2008), or fear of being without one's phone (Yildirim & Correia, 2015).

The lack of a consistent and validated conceptual definition of problematic phone use has created noticeable diversity in prevalence data, and a lack of both reliability and validity in existing measures (De-Sola Gutiérrez et al., 2016). Many problematic phone use measures were founded on addiction literature (e.g. Bianchi & Phillips, 2005; Chóliz, 2012; Walsh et al., 2010; Yen et al., 2009). Of note, Young's (1998) Internet Addiction Scale (IAS) forms the basis of several mobile/smartphone addiction scales. The IAS is an eight-item measure of internet use, which draws on behavioral addiction criteria for pathological gambling from the DSM-IV (American Psychiatric Association, 1994). However, internet use has drastically changed since the IAS was first published, as the advent of smartphone technology has seen the internet become more portable and readily accessible. Also, The IAS is a global measure of internet addiction, however the study of problematic smartphone use has now evolved to examine distinct behaviours, such as social networking, messaging, and mobile internet use. Scales based on Young's (1998) criteria may omit vital information regarding the effects of device portability and ubiquitous connectivity. Defining and measuring these behaviors as an addiction to the device is limiting and problematic (Starcevic & Aboujaoude, 2016), as focusing narrowly on addiction behaviors may not be highly relevant for assessing problematic affect, behaviors and cognitions between humans and information technologies.

Confining the definition of problematic phone use to an addiction does not account for other negative smartphone experiences. Research concerning mobile technology use in organizational settings has revealed a common theme: a perceived obligation to be constantly available to others via mobile/smartphone devices. Participants within Mazmanian, Yates, and Orlikowski's (2006) study described an implicit expectation to frequently check their mobile phones, and explained how their devices established a reputation for communicative responsiveness. Their results suggest a dysfunctional cycle whereby employees are increasingly expected to be contactable the more they make themselves available to be contacted. Middleton's (2007) study found that colleagues expected prompt replies from respondents who owned a mobile phone because they could access their email anywhere, anytime. Since the development of smartphones, these devices are now more readily accessible to the general public and these unrealistic expectations of constant connection may have become a common facet of our social communications.

It is important to note that mobile/smartphone users often acknowledge the dysfunctional aspects of constant connectivity alongside other beneficial qualities. Jarvenpaa, Lang, and Tuunainen (2005) described how the same connectivity that empowers mobile phone users to take control of their workload also prevents users from effectively distancing themselves from others, known as the empowerment-enslavement paradox. Participants within Ames' (2013) qualitative study judged others based on their responsiveness, and would often apply varying degrees of social pressure to coerce others into responding promptly (e.g., by means of teasing or shunning). Similarly, this type of social censure was reciprocated when participants were not as responsive as their peers expected. Therefore, while ubiquitous connectivity can enhance social presence and empower mobile/smartphone users, this does not negate the consequences of social absence. This facet of problematic phone use does not appear to involve a compelling desire to perform some behavior (similar to internet gaming disorder), but instead an undesired feeling of being required to meet the expectations of others.

Seo, Kim, and David (2015) described connectedness as the inclination to stay connected with others and remain available for others to connect with via mobile devices. They suggested that people with a higher need for social assurance are more likely to make themselves available to others and are more likely to engage in problematic phone use. Seo and colleagues developed a six-item scale of connectedness, which measured one's inclination to remain constantly connected, to be available to others, and to respond promptly to phone calls and messages. While their notion of connectedness acknowledges a perceived need to be constantly available to others through mobile technology, it does not account for the stress incurred from having to remain constantly connected, and no formal validity tests were performed beyond face validity.

Research on problematic phone use has shown positive correlations with symptoms of depression and anxiety (Elhai, Dvorak, Levine, & Hall, 2017), stress (Samaha & Hawi, 2016), suicidal tendencies (Wang et al., 2014), and anxious attachment style (Yuchang, Cuicui, Junxiu, & Junyi, 2017). Perceived social support has been found to moderate the relationship between depression and adolescent problematic smartphone use (Fu et al., 2020). Odgers (2018) reviewed such findings and concluded that further testing, with suitably heterogeneous samples and improved scientific methods, are required to decipher the actual psychopathological implications of smartphone use. Improved measurement should form the bedrock for advancing this science.

1.2. Scale development validity

Previous scale validation studies in this area have suffered from numerous limitations, including inadequate sample heterogeneity. For example, some studies utilized convenience samples of university students (e.g. Igarashi et al., 2008; Rutland et al., 2007; Yildirim & Correia, 2015). Samples comprised solely of university students are more homogenous than community samples; they may poorly represent population factors and effect sizes, and often include significant numbers of invalid responses (e.g., Hanel & Vione, 2016; Huang, Curran, Keeney, Poposki, & DeShon, 2012; Peterson, 2001). Furthermore, past research has mostly focussed on adolescents and young adults. Those who have been exposed to the technology from a young age are thought to exhibit more problematic phone use (Bianchi & Phillips, 2005), while older individuals may be less likely to embrace the technology and are therefore not as greatly impacted (Billieux et al., 2008). Different age groups have demonstrated varied use and prioritization of their mobile phones (Kumar & Lim, 2008), so scales developed using narrow age ranges may perform differently when administered to different age groups. Also, many studies had fewer than 100 male participants, making gender effects difficult to confirm (e.g. Bianchi & Phillips, 2005; Kwon et al., 2013; Rutland et al., 2007). Given that females are more likely to exhibit behaviors indicative of mobile phone dependence (Billieux et al., 2008), it is necessary to obtain suitable numbers of males, youth, and adults, and test for item invariance through differential item functioning (DIF) checks, to develop a valid measure of problematic smartphone use.

Previous measures of problematic phone use were limited to classical test theory (CTT) methods, but rarely followed best practice. Item response theory (IRT) methods are considered more state-of-the-science and provide important information for developing highly valid measures (Embretson & Reise, 2000; Ostini & Nering, 2006). For example, Streiner (2010) argues that measures developed using CTT can falsely assume all items are of equal value or weight, and such scales are often longer than necessary because they include uninformative items. In contrast, IRT methods help create brief, yet reliable and valid measures, by determining which items are most informative, whether response options are appropriate, and whether groups respond differently to some items (Embretson & Reise, 2000; Ostini & Nering, 2006; Streiner, 2010). We conclude that scale development in the 21st Century should include both CTT and IRT methods, following best practice procedures.

1.3. Study aims

There are considerable limitations in the current literature regarding how the stress of being constantly connected to others via smartphone technology can be appropriately measured. There is currently no scale of problematic phone use that has demonstrated highly valid measurement of related constructs. This study aimed to develop and validate a psychometrically sound measure of the stress incurred from maintaining

constant connectivity through smartphones, by using more advanced analyses (e.g., IRT) and a critical approach. We operationalized this approach by employing an item pool and requiring all final items, and the resulting scale, to demonstrate high psychometric properties and a lack of DIF. We also examined how connectivity stress relates to psychosocial factors (e.g., depression, anxiety, stress, suicidality, attachment style, and social support), hypothesizing positive associations between smartphone connectivity stress and psychopathology symptoms, consistent with the extant literature.

2. Method

2.1. Participants

Participants for two surveys (Time 1 [T1] and Time 2 [T2]) were obtained through Facebook and Instagram advertising, as well as snowballing emails asking for volunteers to complete the Smartphones & Mental Health Survey (SPMHS). Inclusion criteria were: aged 14+, internet access, and English proficiency. All participants were confidential volunteers and provided informed consent. Ethics approval was granted by the host institution (H19153). There were no rewards, and university student research participants were not included.

The T1 survey included 814 participants, 480 (59.0%) were female, 288 (35.4%) male, and 46 (5.6%) non-binary. They were aged 14–80 ($M = 25.58$, $SD = 12.06$). Participants were predominantly Caucasian/white (52.0%), and Asian (16.2%); 28.7% were urban residents, 61.2% resided in suburbs/small towns, and 10.1% lived rurally. T2 included 190 participants; 66.8% were female, 23.2% male, 10.0% non-binary, and were aged 14–80 ($M = 27.81$, $SD = 13.73$).

2.2. Item pool

The Smartphone Connectivity Stress Scale (SCSS) was developed following best practice scale development guidelines (e.g. DeVellis, 2016; Reise & Waller, 2009; Thomas, 2011). Smartphone connectivity stress was defined as the stress incurred from the perceived need to be constantly accessible to others via smartphone technology. Items reflected behaviors related to maintaining connections, attitudes towards remaining connected to others, affective reactions to interrupted connections, and expectations of one's availability. Twenty pool items were adapted from existing measures (Bianchi & Phillips, 2005; Kwon et al., 2013; Seo et al., 2015; Trub & Barbot, 2016; Walsh et al., 2010; Yildirim & Correia, 2015). These items were slightly modified and reworded for clarity, and to better capture the underlying construct. Six items came from qualitative literature (Ames, 2013; Mazmanian et al., 2006; Middleton, 2007), and four author-created items captured additional smartphone connectivity stress attributes. The 30 items were confirmed through consensus discussion by six SPMHS researchers on content adequacy and clarity.

A five-point discrete visual analogue response set was developed for all items. Only anchor points were verbally labelled, as research has shown verbally labelled responses do not form equal response points (Ware & Gandek, 1994). Only labelling anchor points helps obtain near-interval level data via equidistant response options. The current study opted for a five-point response set, anchored "1 = not at all true of me" and "5 = extremely true of me." For the SPMHS, midpoints of all measures were labelled with numbers to better approximate interval level data.

2.3. Measures

Connectedness. The item pool included all six Connectedness items (Seo et al., 2015) as potential scale items and for concurrent validity checks. This measure was developed to assess inclination and investment in being connected to others. The response options were altered to be consistent with pool items but maintained a five-point scale. An example item is: "I respond to phone messages as soon as possible." Previous study found evidence of unidimensionality and moderate internal consistency, $\alpha = 0.85$. An EFA for this study (principal axis factoring, PAF) showed one factor explaining 44.6% of common variance, with loadings > 0.60, $h^2 > 0.36$. For this study, internal consistency was moderate, McDonald's $\omega_t = 0.82$, $\alpha = 0.82$.

The *Depression, Anxiety, and Stress Scales* (Lovibond & Lovibond, 1995) consist of three seven-item scales assessing symptoms of depression, anxiety and stress. Participants rate each state over the past week using a 4-point severity/frequency response set, anchored "0 = did not apply to me at all" and "3 = applied to me very much or most of the time." An example depression item is: "I felt that life was meaningless," an example anxiety item is: "I felt I was close to panic," and an example stress item is: "I found it hard to wind down." Scores for each subscale are calculated by summing the scores for the relevant items, before multiplying by two to calculate the final score. Higher scores indicate more negative emotional states of depression, anxiety or stress. For Depression, McDonald's $\omega_t = 0.96$, $\alpha = 0.94$; Anxiety, McDonald's $\omega_t = 0.92$, $\alpha = 0.91$; Stress, McDonald's $\omega_t = 0.91$, $\alpha = 0.88$.

The *Anxious Attachment-Brief Scale* (Wilkinson, 2011) is a six-item scale measuring anxious attachment style derived from the Experiences in Close Relationships instrument (Wilkinson, 2011), and was validated in the present study. Participants rate the extent to which they agree with each statement using a 5-point response set, anchored "1 = strongly disagree" and "5 = strongly agree." An example item is: "I worry a lot about my relationships." Scores are calculated by averaging item responses, with higher scores indicating higher levels of anxious attachment. For this study, McDonald's $\omega_t = 0.94$, $\alpha = 0.92$.

The *Multidimensional Scale of Perceived Social* Support (Zimet, Dahlem, Zimet, & Farley, 1988) consists of three four-item subscales assessing perceived social support from family, friends, and a significant other. Participants rate the extent to which they agree with each statement using a 7-point response set, anchored "1 = very strongly disagree" and "7 = very strongly agree." An example family item is: "I can talk about my problems with my family," an example friend item is: "My friends really try to help me," and an example significant other item is: "There is a special person who is around when I am in need." Scores for each subscale are totaled, with higher scores indicating higher levels of perceived social support. For Family, McDonald's $\omega_t = .95$, $\alpha = 0.94$; Friends, McDonald's $\omega_t = 0.94$, $\alpha = 0.94$; Significant Other, McDonald's $\omega_t = 0.95$, $\alpha = 0.94$.

The *Suicidality Scale* (Harris et al., 2020) is an eight-item scale measuring affective and cognitive aspects of suicidality. Items use various response sets and are totaled, with higher scores indicating higher suicidal symptoms. An example item is: "Recently, how much do you wish to die?" The scale was recently redeveloped from the Suicidal Affect-Behaviors-Cognition Scale (Harris et al., 2015; Harris, Lello, & Willcox, 2017), with improved psychometric properties. For this study, McDonald's $\omega_t = 0.97$, $\alpha = 0.96$.

2.4. Procedure

The SPMHS included two confidential online surveys. The only identifying information requested were email addresses of participants agreeing to complete the T2 survey. SCSS items were randomized to reduce order bias. The exit page included a debriefing statement and links to relevant support sites, with encouragement to utilize these as required. Two weeks following the T1 survey, participants were invited via email to complete the T2 survey, which also included the full SCSS item pool.

2.5. Statistical analysis

Data cleansing involved the identification and treatment of univariate and multivariate outliers and careless responses. Missing values were replaced through expectation-maximization (Dong & Peng, 2013; Rubin,

Witkiewitz, Andre, & Reilly, 2007). Careless responses (inadvertently or intentionally inaccurate) were examined following expert recommendations (Dupuis, Meier, & Cuneo, 2019; Huang et al., 2012). We identified problematic responses through psychometric antonyms, individual reliability coefficients, long strings, and Mahalanobis' distance. Based on these results, we removed 20 problematic cases (2.4%).

We used EFA to reduce the SCSS item pool to items that formed the most valid representation of the latent trait, and IRT analyses identified the most informative items. DIF analyses tested invariance by gender, age, ethnicity and residence. Gender and ethnicity were dichotomized as female/male and white/other, respectively. Coefficient α and McDonald's omega total (ω_t) assessed internal consistency. Exploratory bifactor analysis produced McDonald's omega hierarchal (ω_h) scores to provide reliability estimates of general factor variance (Revelle & Zinbarg, 2009). Revelle and Zinbarg (2009) have shown that ω_h and ω_t provide a more realistic estimate of a scale's internal consistency than most reliability measures. Bootstrapped confidence intervals were computed, as these are less prone to misinterpretation and provide information about the size of the effect beyond *p*-values (Wood, 2005). Test-retest reliability was established using correlations between T1 and T2 data. Analyses used R v.4.0.3 (R Core Team, 2020), packages: psych (Revelle, 2020), ltm (Rizopoulos, 2006), lordif (Choi, Gibbons, & Crane, 2011), and careless (Yentes & Wilhelm, 2018).

3. Results

3.1. Time 1 EFA

Item pool factorability was supported, KMO = 0.95. We conducted iterative exploratory factor analyses, following expert recommendations (Costello & Osborne, 2005; Henson & Roberts, 2006). We sought to form a measure with the following recommended standards: five or more items, loadings ≥ 0.50; and communalities ≥ 0.40. PAF analyses with direct oblimin rotation were used to identify and remove worst fitting items, one by one. The final EFA indicated a six-item unidimensional solution (Appendix). Table 1 shows skew was low, and all items loaded strongly on a single factor. Communalities and item-total correlations were all moderately high, indicating items measure a common latent trait. The SCSS demonstrated good internal consistency ($\omega_t = 0.91$; α = 0.87). McDonald's $\omega_h = 0.80$, indicating the items explained 80% of general factor variance. Additional analyses were conducted on adolescent (aged 14–18, $n = 353$) and adult subsamples (aged 19–80, $n = 461$). Factor structure and internal consistency were similar across age groups but with slightly higher values for adults, loadings = 0.73–0.79, h^2 = 0.54–0.62. For adolescents, loadings = 0.61–0.75, h^2 = 0.37–0.56. The adult subsample demonstrated slightly higher internal consistency (ω_t = 0.92; α = 0.88) than adolescents ($\omega_t = 0.89$; α = 0.84). Explained general factor variance was also higher with adults, McDonald's $\omega_h = 0.82$, than adolescents, McDonald's $\omega_h = 0.72$.

Table 1
Properties and factor analysis of the smartphone connectivity stress scale (SCSS).

Item	*M*	*SD*	Skew	Kurtosis	Loading	h^2	Item-total *r*
1. Missed contact	3.00	1.32	.01	−1.17	.78	.60	.71
2. Couldn't be reached	3.06	1.26	-.07	−1.07	.75	.57	.69
3. Broken connection	2.63	1.30	.39	−0.95	.75	.56	.69
4. No battery/power	3.11	1.36	-.11	−1.23	.71	.50	.65
5. No Wi-Fi/signal	2.72	1.33	.29	−1.08	.71	.50	.66
6. Messages not checked	2.59	1.25	.39	−0.85	.70	.49	.65

Note. Factor Analysis = principal axis factoring with direct oblimin rotation, Loading = factor loading, h^2 = communalities, item-total *r* = corrected item-total correlation, *SE* of skew = 0.09, *SE* of kurtosis = 0.17, 1st eigenvalue = 3.67, 2nd eigenvalue = 0.66, total variance explained = 53.4%.

3.2. Item response theory analysis

After establishing unidimensionality, we conducted IRT analyses to assess item information levels across the trait spectrum. As SCSS items were all polytomous, the graded response model (GRM) was deemed most suitable. An ANOVA showed that the unconstrained GRM model was a better fit than a constrained model, LRT = 15.09 (df = 5), $p < .01$ (Ostini & Nering, 2006). Therefore, we used the unconstrained GRM which allows for unequal item weights. Item discrimination levels (*a*) indicate item difficulty, or how important the item is. β parameters denote the item's ability to discriminate at low to high levels of the latent trait. As shown in Table 2, all SCSS items had relatively high discrimination levels ($a > 1.90$) and demonstrated a broad range of difficulty across response categories. These findings offer evidence that all items provide valuable information across the spectrum of smartphone connectivity stress. However, the item information values (IF) indicated that the information captured by individual items ranged from 13.7% to 20.7% of total scale information, meaning items are not equally weighted. Items 1 'missed contact' and 2 'couldn't be reached' captured more information on the latent trait, demonstrating slightly greater importance of these attributes.

Fig. 1 shows the item information curves, illustrating item measurement across the latent trait spectrum. Item curves represent the β values within Table 2. Where the lines taper off towards the left denote βl, and where the line tapers off towards the right denotes β4. The areas under the lines represent the amount of information each item captures (IF). In addition, item response category characteristic curves (available on request) showed the six items adequately discriminated between individual responses, demonstrating the validity of a five-point response set.

3.3. Time 2 EFA and test-retest reliability

We then tested the validity of the initial scale development outcomes with the T2 data ($n = 190$), which showed KMO = 0.89. We chose to do EFA rather than Confirmatory Factor Analysis (CFA), as CFA can artificially inflate communalities and factor loadings (e.g. Schmitt, 2011). We again employed PAF with direct oblimin rotation. As shown in Table 3, all items had loadings > 0.50 and $h^2 > 0.40$, exceeding Costello and Osborne's (2005) criteria for a strong, stable factor. The SCSS demonstrated good test-retest reliability (two weeks) for the total sample, $r(188) = 0.82$; and adult subsample, $r(109) = 0.85$. Slightly lower test-retest reliability was observed in the adolescent subsample, $r(77) = 0.74$, suggesting that the construct may become more stable with age. Overall, the results demonstrate that the SCSS is stable across time.

Table 2
Graded response model analysis of the smartphone connectivity stress scale (SCSS).

Item	β_1	β_2	β_3	β_4	*a*	IF	Pct.
1. Missed contact	−1.20	−0.29	0.33	1.18	2.61	7.31	20.7%
2. Couldn't be reached	−1.42	−0.43	0.27	1.33	2.39	6.87	19.4%
3. Broken connection	−0.89	0.03	0.74	1.51	2.33	6.20	17.5%
4. No battery/power	−1.28	−0.40	0.18	1.13	2.04	5.08	14.4%
5. No Wi-Fi/signal	−1.00	−0.04	0.66	1.49	1.96	4.86	13.7%
6. Messages not checked	−0.97	0.03	0.87	1.74	1.95	5.07	14.3%

Note. β_1 = lowest item difficulty threshold; β_4 = fourth response option item difficulty threshold; *a* = item discrimination level; IF = information function; Pct. = percentage of total scale information.

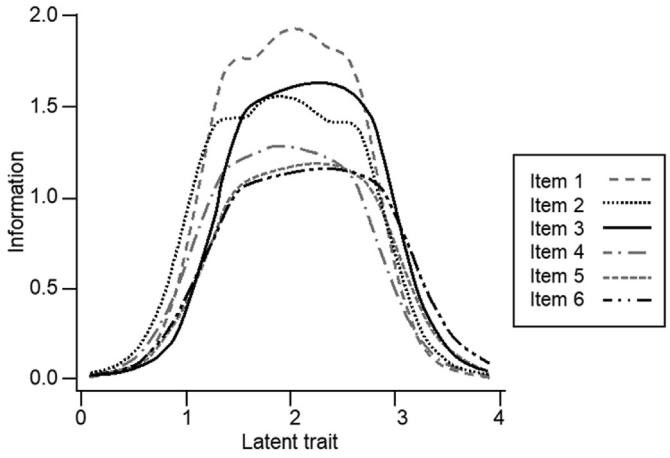

Fig. 1. The Smartphone Connectivity Stress Scale item information curves.

Table 3
Time 2 psychometric properties and factor analysis of the SCSS (n = 190).

Item	*M*	*SD*	Skew	Kurtosis	Loading	h^2	Item total *r*
6. Messages not checked	2.66	1.24	.27	−0.93	.81	.65	.76
4. No battery/ power	3.11	1.36	-.13	−1.19	.80	.64	.75
2. Couldn't be reached	2.93	1.21	.09	−0.91	.77	.59	.73
3. Broken connection	2.53	1.19	.45	−0.63	.77	.60	.73
5. No Wi-Fi/ signal	2.76	1.33	.22	−1.09	.77	.59	.72
1. Missed contact	2.92	1.27	.07	−0.98	.77	.59	.72

Note. Principal axis factoring, direct oblimin rotation. Loading = factor loading; h^2 = communalities, item-total *r* = corrected item-total correlation; *SE* of skew = 0.18; *SE* of kurtosis = 0.35; 1st eigenvalue = 4.04, 2nd eigenvalue = 0.57, total variance explained = 60.9%.

3.4. Differential item functioning

We next tested whether any SCSS items differed by demographic groups in their ability to capture information on the latent trait. We compared patterns by age (14–18 vs. 19–80 years), sex (male vs. female), ethnicity (European/white vs. other), and residence (urban vs. rural). Analyses revealed no evidence of DIF for any items (all pseudo $R^2 < 0.02$; Choi et al., 2011). This provides some confidence that the items function equivalently across these groups.

3.5. SCSS convergent validity & associations with psychosocial factors

After establishing sound psychometric properties for the SCSS, and a lack of DIF, we next examined SCSS convergent validity and associations with psychosocial variables. We conducted partial correlations, controlling for gender and ethnicity, performed correlations separately for adolescents (aged 14–18) and adults (aged 19–80), and calculated bootstrapped confidence intervals (1000 iterations). Table 4 shows evidence of convergent validity through moderately high correlations with Connectedness, a similar measure included in the item pool, but which did not contribute items to the SCSS. As hypothesized, psychopathology symptoms were moderately positively correlated with SCSS scores. In contrast, perceived family support showed low negative correlations with connectivity stress, and perceived friend and partner/significant other support were unrelated.

Table 4
Partial correlations of psychosocial factors with the smartphone connectivity stress scale.

Variable	Total	95% CI	Adolescents	95% CI	Adults	95% CI
Connectedness	.60***	[.55, .65]	.58***	[.50, .65]	.59***	[.51, .65]
Stress	.37***	[.29, .43]	.34***	[.24, .44]	.27***	[.18, .37]
Depression	.32***	[.25, .39]	.28***	[.18, .38]	.21***	[.11, .31]
Anxiety	.35***	[.28, .42]	.33***	[.24, .43]	.23***	[.14, .33]
Anxious attach	.41***	[.35, .47]	.33***	[.25, .42]	.35***	[.26, .43]
Suicidality	.31***	[.24, .37]	.27***	[.16, .37]	.40***	[.31, .48]
Family support	-.17***	[-.24, −.10]	-.12*	[-.22, −.02]	-.08	[-.18, .02]
Friend support	-.05	[-.12, .03]	.02	[-.09, .13]	-.02	[-.13, .08]
SO support	-.03	[-.10, .04]	-.01	[-.13, .10]	.06	[-.03, .14]

Note. Total sample N = 814; adolescents (aged 14–18) *n* = 353; adults (aged 19–80) *n* = 461; Anxious attach = anxious attachment style; SO = significant other; correlations control for gender (female/male) and ethnicity (European/ other); confidence intervals bootstrapped 1000 iterations.
*$p < .05$; ***$p < .001$.

4. Discussion

In this study, we developed the psychometrically sound SCSS, measuring the stress incurred from maintaining constant connectivity via mobile technology. This was accomplished through a critical analysis of a diverse item pool, CTT and IRT analyses. The SCSS demonstrated validity across demographic groups and showed significant associations with several psychosocial factors. The utility of measuring this construct is highlighted by conditions during the COVID-19 pandemic and the need to carefully examine personal impacts from an increasingly connected world.

We operationalized smartphone connectivity stress as the stress incurred from the perceived need to be constantly accessible to others via smartphone technology. This definition captures a type of interpersonal anxiety, focused on positive impression management by remaining available for others to connect with, and responding promptly to communications. The latent trait studied here shows some consistencies with previous work hypothesizing smartphone connectivity stress might result from not wanting to give a poor impression of being personally connected/contactable (van Deursen, Bolle, Hegner, & Kommers, 2015). Thus, the SCSS represents situational stress in response to a loss of connection with others, which is a more specific and evidence-based trait compared with previous attempts to operationalize this trait as a technological addiction. This contrasts with the several measures of problematic phone and internet use that use addiction-like items. Behavioral addictions, such as online gaming disorder, relate to a personal desire to perform a behavior, and frequently lead individuals to hide those behaviors from others (American Psychiatric Association, 2013). Connectivity stress also differs from the concept of nomophobia, in that we saw limited evidence of the fear of not having a phone as an attribute of the latent trait. However, the main attributes of the construct that emerged from this study was concern for lost social connectivity and meeting the expectations of others, not simply fear of not having one's phone available. This study and previous works show that connectivity stress is the more appropriate construct to be measured and investigated, rather than addiction to a smartphone or social media platform, or fear of not having one's phone.

4.1. Age-group and psychopathology factors

The SCSS demonstrated significant associations with anxious attachment style, symptoms of anxiety, stress, suicidality and depression. Anxious attachment showed a slightly higher association with smartphone connectivity stress than other study variables. This result aligns with research showing anxious attachment positively predicts problematic phone use (Yuchang et al., 2017), and supports Seo and colleague's (2015) notion that those with higher needs to be reassured and accepted are more likely to remain in a state of constant connection via their smartphone. Current findings also concur with previous research showing greater technology-based communications predict psychopathology symptoms (Harris & Aboujaoude, 2016). It is also noteworthy that smartphone connectivity stress did not show meaningful associations with perceived social support. These results may indicate that attachment style and anxiety are the overriding factors here and are not buffered by protective influences of social support.

SCSS psychometric properties were somewhat lower within the adolescents subsample This suggests that the latent trait is somewhat less stable for youth. This could be a result of differing levels of exposure to mobile technology. Adolescents and adults differ in their information technology use (Odgers, 2018; Odgers & Jensen, 2020), and some adolescent participants may have had significantly less experience and autonomy with their devices. Recommendations include longitudinal research and an emphasis on youth support services.

4.2. Psychometric factors

The brief, six-item, SCSS demonstrated strong properties evidenced through critical analysis of the data. This process differed considerably in psychometric rigor with respect to past scale development studies in this area. The SCSS was subjected to a rigorous iterative EFA, and DIF analysis. The use of IRT and CTT provided greater confidence that SCSS items are informative and representative, and the five-point response sets were suitable. In addition, test-retest reliability and EFA analyses confirmed reliability and consistency in items and scale performance over time, and for both adolescents and adults. The SCSS showed concurrent validity through a moderately-high positive correlation with Seo and colleague's (2015) measure of connectedness. The SCSS also demonstrated higher unidimensionality (e.g., higher factor loadings), higher internal consistency, and items were more informative on the latent trait than the comparison measure.

4.3. Limitations and implications for future research

The sample was not balanced on gender but did include an adequate number of male respondents (n = 296) to conduct scale development, and DIF showed no gender effects. This study's age range was broader than most comparable studies, but did not include those under 14 years and had a limited number of adults over 40 years (n = 96). While further study on older adult issues with problematic smartphone use is warranted, our findings encourage change in how we investigate problematic smartphone use and related constructs by considering a broader age range. Survey advertising via Facebook and Instagram was helpful but may have resulted in sampling bias. There may be important differences between individuals who use smartphones but do not use Facebook or Instagram, or do not voluntarily complete surveys. A broader advertising campaign may be helpful in reaching a more diverse sample. However, this sample did represent the full spectrum of the constructs under investigation. All item responses and possible scale total points were endorsed/represented in this sample. This lack of range restriction provides some confidence in interpreting these findings. Therefore, following studies are encouraged to also reach out to broad and diverse participants, who fully represent the spectrum of the construct being investigated. In addition, further studies, using bifactor analysis, EFA, and IRT, could further test the validity of connectivity stress versus addiction-like symptoms in problematic smartphone and internet use.

5. Conclusion

These findings demonstrate that the SCSS is a consistent and quantifiable measure of an already apparent phenomenon. Through the application of CTT and IRT, and in accordance with best-practice scale development, we developed and validated a scale that measures the perceived stress of maintaining constant connectivity with others. This is the first known study to implement IRT in developing a problematic phone use scale and sets a precedent for future research. The results of this study contribute to the existing literature on problematic phone use, and challenges the prevalent stance of classifying problematic phone use as an addiction, or as a factor only relevant to adolescents. The public domain SCSS provides opportunities for further study of how smartphone connectivity stress relates to psychopathological and interpersonal factors.

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Open access data

Data has been uploaded to the Open Science Foundation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

The Smartphone Connectivity Stress Scale (SCSS).

Instructions to test administrators: Present the scale as shown below.

The following statements are concerned with how you use your smartphone or mobile phone. Carefully read each statement and indicate how typical it is of you according to the scale below.

Not at all true of me 1——— 2 ——— 3 ——— 4 ——— 5 Extremely true of me.

1. If I did not have my phone with me, I would be nervous someone might have tried to contact me
2. If I did not have my phone with me, I would be worried others could not reach me
3. If I did not have my phone with me, I would be anxious my connection to others would be broken
4. I become stressed when my phone is running on low battery, or is out of power
5. I become worried when there's no Wi-Fi connection or mobile signal
6. I become anxious if I haven't checked my phone messages for some time

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Author. Text Revision.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). https://doi.org/10.1176/appi.books.9780890425596.

Ames, M. G. (2013). Managing mobile multitasking: The culture of iPhones on stanford campus. In *Paper presented at the proceedings of the ACM conference on computer supported cooperative work*. CSCW.

Bianchi, A., & Phillips, J. G. (2005). Psychological predictors of problem mobile phone use. *CyberPsychology and Behavior, 8*(1), 39–51. https://doi.org/10.1089/cpb.2005.8.39

Billieux, J., Van Der Linden, M., & Rochat, L. (2008). The role of impulsivity in actual and problematic use of the mobile phone. *Applied Cognitive Psychology, 22*(9), 1195–1210. https://doi.org/10.1002/acp.1429

Choi, S., Gibbons, L. E., & Crane, P. K. (2011). Lordif: An R package for detecting differential item functioning using iterative hybrid ordinal logistic regression/item response theory and Monte Carlo simulations. *Journal of Statistical Software, 39*(8), 1. https://doi.org/10.18637/jss.v039.i08

Chóliz, M. (2012). Mobile-phone addiction in adolescence: The test of mobile phone dependence (TMD). *Progress in Health Sciences, 2*(1), 33–44. Retrieved from https://www.researchgate.net/publication/284690452_Mobile-phone_addiction_in_adolescence_The_Test_of_Mobile_Phone_Dependence_TMD.

Costello, A. B., & Osborne, J. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research and Evaluation, 10*(7), 1–9. Retrieved from https://www.semanticscholar.org/paper/Best-Practices-in-Exploratory-Factor-Analysis%3A-Four-Osborne-Costello/d81c1f5a196d33fe734affe285e4f428fd3aea46.

De-Sola Gutiérrez, J., Rodríguez de Fonseca, F., & Rubio, G. (2016). Cell-phone addiction: A review. *Frontiers in Psychiatry, 7*, 175. https://doi.org/10.3389/fpsyt.2016.00175

van Deursen, A. J. A. M., Bolle, C. L., Hegner, S. M., & Kommers, P. (2015). Modeling habitual and addictive smartphone behavior: The role of smartphone usage types, emotional intelligence, social stress, self-regulation, age, and gender. *Computers in Human Behavior, 45*, 411–420. https://doi.org/10.1016/j.chb.2014.12.039

DeVellis, R. F. (2016). *Scale development: Theory and applications*. Thousand Oaks, CA, US: Sage publications, Inc.

Dong, Y., & Peng, C.-Y. J. (2013). Principled missing data methods for researchers. *SpringerPlus, 2*(1), 222. https://doi.org/10.1186/2193-1801-2-222

Dupuis, M., Meier, E., & Cuneo, F. (2019). Detecting computer-generated random responding in questionnaire-based data: A comparison of seven indices. *Behavior Research Methods, 51*(5), 2228–2237. https://doi.org/10.3758/s13428-018-1103-y

Elhai, J. D., Dvorak, R. D., Levine, J. C., & Hall, B. J. (2017). Problematic smartphone use: A conceptual overview and systematic review of relations with anxiety and depression psychopathology. *Journal of Affective Disorders, 207*, 251–259. https://doi.org/10.1016/j.jad.2016.08.030

Embretson, S. E., & Reise, S. P. (2000). *Item response theory for psychologists*. Mahwah, NJ: Lawrence Erlbaum Associates.

Fu, L., Wang, P., Zhao, M., Xie, X., Chen, Y., Nie, J., et al. (2020). Can emotion regulation difficulty lead to adolescent problematic smartphone use? A moderated mediation model of depression and perceived social support. *Children and Youth Services Review, 108*, 104660. https://doi.org/10.1016/j.childyouth.2019.104660

Hanel, P. H. P., & Vione, K. C. (2016). Do student samples provide an accurate estimate of the general public? *PLOS ONE, 11*(12), Article e0168354. https://doi.org/10.1371/journal.pone.0168354

Harris, K. M., & Aboujaoude, E. (2016). Online friendship, romance, and sex: Properties and associations of the online relationship initiation scale. *Cyberpsychology, Behavior, and Social Networking, 19*(8), 487–493. https://doi.org/10.1089/cyber.2016.0164

Harris, K. M., Lello, O. D., & Willcox, C. H. (2017). Reevaluating suicidal behaviors: Comparing assessment methods to improve risk evaluations. *Journal of Psychopathology and Behavioral Assessment, 39*(1), 128–139. https://doi.org/10.1007/s10862-016-9566-6

Harris, K. M., Syu, J. J., Lello, O. D., Chew, Y. L. E., Willcox, C. H., & Ho, R. H. M. (2015). The ABC's of suicide risk assessment: Applying a tripartite approach to individual evaluations. *PloS One, 10*(6), Article e0127442. https://doi.org/10.1371/journal.pone.0127442

Harris, K. M., Wang, L., So, C., Mu, M., Zhang, W., Wang, W., … Ho, R. C. (2020). *Developing open science state-of-the-science psychosocial measures: The Suicidality Scale 1.0*. submitted for publication.

Henson, R. K., & Roberts, J. K. (2006). Use of exploratory factor analysis in published research: Common errors and some comment on improved practice. *Educational and Psychological Measurement, 66*(3), 393–416. https://doi.org/10.1177/0013164405282485

Huang, J. L., Curran, P. G., Keeney, J., Poposki, E. M., & DeShon, R. P. (2012). Detecting and deterring insufficient effort responding to surveys. *Journal of Business and Psychology, 27*(1), 99–114. https://doi.org/10.1007/s10869-011-9231-8

Igarashi, T., Motoyoshi, T., Takai, J., & Yoshida, T. (2008). No mobile, no life: Self-perception and text-message dependency among Japanese high school students. *Computers in Human Behavior, 24*(5), 2311–2324. https://doi.org/10.1016/j.chb.2007.12.001

Jarvenpaa, S. L., Lang, K. R., & Tuunainen, V. K. (2005). Friend or foe? The ambivalent relationship between mobile technology and its users. In C. Sørensen, Y. Yoo, K. Lyytinen, & J. I. DeGross (Eds.), *Designing ubiquitous information environments: Socio-technical issues and challenges* (Vol. 185, pp. 29–42). Boston, MA: Springer.

Kumar, A., & Lim, H. (2008). Age differences in mobile service perceptions: Comparison of generation Y and baby boomers. *Journal of Services Marketing, 22*(7), 568–577. https://doi.org/10.1108/08876040810909695

Kwon, M., Lee, J. Y., Won, W. Y., Park, J. W., Min, J. A., Hahn, C., … Kim, D. J. (2013). Development and validation of a smartphone addiction scale (SAS). *PLoS One, 8*(2), Article e56936. https://doi.org/10.1371/journal.pone.0056936

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the depression anxiety stress scales (DASS) with the beck depression and anxiety inventories. *Behaviour Research and Therapy, 33*(3), 335–343. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/7726811.

Mazmanian, M. A., Yates, J., & Orlikowski, W. J. (2006). Ubiquitous email: Individual experiences and organizational consequences of BlackBerry use. In *Paper presented at the proceedings of the 65th annual meeting of the academy of management, Atlanta, GA*.

Middleton, C. A. (2007). Illusions of balance and control in an always-on environment: A case study of BlackBerry users. *Continuum, 21*(2), 165–178. https://doi.org/10.1080/10304310701268695

Odgers, C. L. (2018). Smartphones are bad for some teens, not all. *Nature, 554*(7693), 432–434. https://doi.org/10.1038/d41586-018-02109-8

Odgers, C. L., & Jensen, M. R. (2020). Annual research review: Adolescent mental health in the digital age: Facts, fears, and future directions. *Journal of Child Psychology and Psychiatry, 61*(3), 336–348. https://doi.org/10.1111/jcpp.13190

Ostini, R., & Nering, M. L. (2006). *Polytomous item response theory models*. Thousand Oaks, CA: Sage.

Peterson, R. A. (2001). On the use of college students in social science research: Insights from a second-order meta-analysis. *Journal of Consumer Research, 28*(3), 450–461. https://doi.org/10.1086/323732

R Core Team. (2020). R: A language and environment for statistical computing (version 4.0.3): R foundation for statistical computing. Retrieved from https://www.R-project.org/.

Reise, S. P., & Waller, N. G. (2009). Item response theory and clinical measurement. *Annual Review of Clinical Psychology, 5*, 27–48. https://doi.org/10.1146/annurev.clinpsy.032408.153553

Revelle, W. (2020). *psych: Procedures for psychological, psychometric, and personality research (Version 1.9.12.31)* [R package version 3.6.2]. Evanston, IL: Northwestern University. Retrieved from https://personality-project.org/r/psych/psych-manual.pdf.

Revelle, W., & Zinbarg, R. (2009). Coefficients alpha, beta, omega, and the glb: Comments on sijtsma. *Psychometrika, 74*(1), 145–154. https://doi.org/10.1007/s11336-008-9102-z

Rizopoulos, D. (2006). ltm: An R package for latent variable modeling and item response analysis. *Journal of Statistical Software, 17*(5), 1–25. https://doi.org/10.18637/jss.v017.i05

Rubin, L. H., Witkiewitz, K., Andre, J. S., & Reilly, S. (2007). Methods for handling missing data in the behavioral neurosciences: Don't throw the baby rat out with the bath water. *Journal of Undergraduate Neuroscience Education, 5*(2), A71–A77. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3592650/.

Rutland, J., Sheets, T., & Young, T. (2007). Development of a scale to measure problem use of short message service: The SMS Problem Use Diagnostic Questionnaire. *CyberPsychology and Behavior, 10*(6), 841–843. https://doi.org/10.1089/cpb.2007.9943

Samaha, M., & Hawi, N. S. (2016). Relationships among smartphone addiction, stress, academic performance, and satisfaction with life. *Computers in Human Behavior, 57*, 321–325. https://doi.org/10.1016/j.chb.2015.12.045

Schmitt, T. A. (2011). Current methodological considerations in exploratory and confirmatory factor analysis. *Journal of Psychoeducational Assessment, 29*(4), 304–321. https://doi.org/10.1177/0734282911406653

Seo, M., Kim, J. H., & David, P. (2015). Always connected or always distracted? ADHD symptoms and social assurance explain problematic use of mobile phone and multicommunicating. *Journal of Computer-Mediated Communication, 20*(6), 667–681. https://doi.org/10.1111/jcc4.12140

Starcevic, V., & Aboujaoude, E. (2016). Internet addiction: Reappraisal of an increasingly inadequate concept. *CNS Spectrums, 22*(1), 1–7. https://doi.org/10.1017/S1092852915000863

Streiner, D. L. (2010). Measure for measure: New developments in measurement and item response theory. *Canadian Journal of Psychiatry, 55*(3), 180–186. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20370969.

Thomas, M. L. (2011). The value of item response theory in clinical assessment: A review. *Assessment, 18*(3), 291–307. https://doi.org/10.1177/1073191110374797

Trub, L., & Barbot, B. (2016). The paradox of phone attachment: Development and validation of the young adult attachment to phone scale (YAPS). *Computers in Human Behavior, 64*, 663–672. https://doi.org/10.1016/j.chb.2016.07.050

Van Bavel, J. J., Baicker, K., Boggio, P. S., Capraro, V., Cichocka, A., Cikara, M., et al. (2020). Using social and behavioural science to support COVID-19 pandemic response. *Nature Human Behaviour*, 1–12.

Walsh, S. P., White, K. M., & Young, R. M. (2010). Needing to connect: The effect of self and others on young people's involvement with their mobile phones. *Australian Journal of Psychology, 62*(4), 194–203. https://doi.org/10.1080/00049530903567229

Wang, P.-W., Liu, T.-L., Ko, C.-H., Lin, H.-C., Huang, M.-F., Yeh, Y.-C., et al. (2014). Association between problematic cellular phone use and suicide: The moderating effect of family function and depression. *Comprehensive Psychiatry, 55*(2), 342–348. https://doi.org/10.1016/j.comppsych.2013.09.006

Ware, J. J. E., & Gandek, B. (1994). The SF-36 health survey: Development and use in mental health research and the IQOLA project. *International Journal of Mental Health, 23*(2), 49–73. https://doi.org/10.1080/00207411.1994.11449283

Wilkinson, R. B. (2011). Measuring attachment dimensions in adolescents: Development and validation of the experiences in close relationships - revised - general short form. *Journal of Relationships Research, 2*(1), 53–62. https://doi.org/10.1375/jrr.2.1.53

Wood, M. (2005). Bootstrapped confidence intervals as an approach to statistical inference. *Organizational Research Methods, 8*(4), 454–470. https://doi.org/10.1177/1094428105280059

Yen, C.-F., Tang, T.-C., Yen, J.-Y., Lin, H.-C., Huang, C.-F., Liu, S.-C., et al. (2009). Symptoms of problematic cellular phone use, functional limpairment and its association with depression among adolescents in southern taiwan. *Journal of Adolescence, 32*(4), 863–873. https://doi.org/10.1016/j.adolescence.2008.10.006

Yentes, R. D., & Wilhelm, F. (2018). Procedures for computing indices of careless responding. R package (Version 1.1.3.). Retrieved from https://github.com/ryentes/careless.

Yildirim, C., & Correia, A.-P. (2015). Exploring the dimensions of nomophobia: Development and validation of a self-reported questionnaire. *Computers in Human Behavior, 49*, 130–137. https://doi.org/10.1016/j.chb.2015.02.059

Young, K. S. (1998). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology and Behavior, 1*(3), 237–244. https://doi.org/10.1089/cpb.1998.1.237

Yuchang, J., Cuicui, S., Junxiu, A., & Junyi, L. (2017). Attachment styles and smartphone addiction in Chinese college students: The mediating roles of dysfunctional attitudes and self-esteem. *International Journal of Mental Health and Addiction, 15*(5), 1122–1134. https://doi.org/10.1007/s11469-017-9772-9

Zimet, G. D., Dahlem, N. W., Zimet, S. G., & Farley, G. K. (1988). The multidimensional scale of perceived social support. *Journal of Personality Assessment, 52*(1), 30–41. https://doi.org/10.1207/s15327752jpa5201_2