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Abstract

Given the many technological advances over the past two decades, a small minority of young people are at risk of problematic use or becoming addicted to these technologies (including activities on the internet and smartphones). Many brief psychometric scales have been developed to assess those at risk of problematic use or addiction including the six-item Smartphone Application-Based Addiction Scale [SABAS], the six-item Bergen Social Media Addiction Scale [BSMAS], and the nine-item Internet Gaming Disorder Scale-Short Form [IGDS-SF9]). However, to date, the reproducibility of these three scales has only been examined over a short period of time (e.g., two weeks), and it is unclear whether they are time invariant across a longer period (e.g., three months). Given the emergence of internet and smartphone addiction in Chinese population, the present study translated the three instruments into Chinese and recruited 640 university students (304 from Hong Kong [99 males] and 336 from Taiwan [167 males]) to complete the three scales twice (baseline and three months after baseline). Multigroup confirmatory factor analysis (MGCFA) was applied to examine the time invariance. The intraclass correlation coefficient (ICC) was used to assess the relative reliability, and the percentage of smallest real difference (SRD%) was utilized to explore the absolute reliability for the three scales. MGCFA showed that all three scales were time invariant across three months. ICC demonstrated that all the scales were satisfactory in reproducibility (0.82 to 0.94), and SRD% indicated that all the scales had acceptable measurement noises (23.8 to 29.4). In conclusion, the short, valid, reliable, and easy-to-use Chinese SABAS, BSMAS, and IGDS-SF9 show good properties across periods of three months.

Keywords: online addictions; smartphone addiction; social media addiction; internet gaming disorder; time invariance

Introduction

Advances in internet and smartphone technology has led to a large growth the use of internet-based applications and platforms among young populations (Cheng & Li, 2014; Kuss & Griffiths, 2012; Kuss, Griffiths, Karila, & Billieus, 2014; Ryan, Chester, Reece, & Xenos, 2014). Consequently, healthcare providers have observed potential health problems and risks resulting from overuse and dependency on using such technology among a small minority of individuals. For example, excessive use of the internet and/or smartphones may cause musculoskeletal discomfort, poor sleep quality, daytime sleepiness, and depressed mood states (Yang, Chen, Huang, Lin, & Chang, 2017; Ikeda & Nakamura, 2014; Nathan & Zeitzer, 2013). Many of these problematic behaviors in their most extreme form have been described as behavioral addictions featuring similar components and consequences irrespective of the behavioral focus (Griffiths, 2000; 2005).

The American Psychiatric Association (2013) included a tentative internet-related behavior in the form internet gaming disorder (IGD) in the latest (fifth) edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). Meanwhile, many mental health professionals claim that other excessive behaviors related to internet or smartphone use also warrant attention in relation to mental health (Csibi, Griffiths, Cook, Demetrovics, & Szabo, 2018; Griffiths, 2000; Monacis, De Palo, Griffiths, & Sinatra, 2017). Although the terms describing behavioral problems associated with problematic technology use (i.e., *addiction* vs. *disorder*) do not have a consensus among the scholars (e.g., Brand, Young, Laier, Wölfling, and Potenza [2016] propose using the nomenclature in DSM-5), the present study does not distinguish between the terms ‘addiction’ and ‘disorder’ to describe such behavioral problems. The main reason being that *addiction* remains the most frequently used term in the international peer-reviewed literature (Brand et al., 2016).

Nevertheless, most of the historical and contemporary literature agrees that there are two different concepts in internet addiction: generalized and specific internet addictions (Brand, Young, & Laier, 2014; Davis, 2001; Griffiths, 1998, 2000; Montag et al., 2015). Generalized internet addiction, which is defined as a general and multidimensional behavioral pattern of Internet overuse that causes significant negative consequences in an individual's life (Pontes, Kuss, & Griffiths, 2015), has been found to be associated with a variety of comorbid disorders, including attention deficit/hyperactivity disorder, depression (Sariyska, Reuter, Lachmann, & Montag, 2015), social anxiety (Weinstein, Dorani, Elhadif, Bukovza, & Yarmulnik, 2015), and substance abuse (Rücker, Akre, Berchtold, & Suris, 2015).. Other dysfunctions are also found to be related to generalized internet addiction including impaired family functioning, lowered life satisfaction, problematic family interaction (Wartberg, Kriston, Kammerl, Petersen, & Thomasius, 2015), poor emotional wellbeing, and decreased academic performance (Rücker et al. 2015).

Additionally, specific online addictions (Brand, Young, & Laier, 2014; Davis, 2001; Griffiths, 1998, 2000; Montag et al., 2015) such as smartphone addiction, social media addiction, and IGD, share similar features to generalized internet addiction. Therefore, specific online addictions could also be related to poor health outcomes. It should also be noted that smartphone addiction has been defined as a type of specific online addiction by many authors in the contemporary literature (for an overview, see: Billieux, Maurage, Lopez-Fernandez et al., 2015). However, evidence also shows that smartphone addiction is associated with social media addiction particularly because social media use is primarily engaged in on smartphones (Kuss & Griffiths, 2017; Sha, Sariyska, Riedl, Lachmann & Montag, 2018). Smartphone addiction has also been likened to generalized internet addiction because smartphones can be used for many activities such as gambling, gaming, and social networking (Kuss & Griffiths, 2017), and Sha et al. (2018) view smartphone addiction as an internet communication disorder based on their results. The present authors also take the view that it is the applications on smartphones that tend to be the source of problematic behavior and is the main reason that the present study used the Smartphone Application-Based Addiction Scale (SABAS).

In order to quickly assess the risk of addiction related to activities and applications on the internet and smartphone, three ultra-brief psychometric instruments have been developed that have robust psychometric properties. These are the Smartphone Application-Based Addiction Scale (SABAS; Csibi, Demetrovics, & Szabo, 2016), the Bergen Social Media Addiction Scale (BSMAS; Andreassen et al., 2016; Lin et al., 2018), and the nine-item Internet Gaming Disorder Scales-Short Form (IGDS-SF9; Griffiths, 2018; Pontes & Griffiths, 2015). The three instruments were developed with a strong theoretical basis and psychometric tested for their robustness. More specifically, all three scales have high internal consistency (e.g., α=0.81 for SABAS [Csibi et al., 2016]; 0.97 for BSMAS [Monacis et al., 2017]; 0.90 for IGDS-SF9 [Wu et al., 2017]). However, to the best of the present authors' knowledge, there is only a little information concerning test-retest reliability of the three scales (test-retest reliability=0.83 for SABAS [Lin et al., 2018] and 0.87 for IGDS-SF9 [Wu et al., 2017]). Furthermore, no previous studies have ever examined whether any of them are time invariant across several months.

Time invariance is a specific type of measurement invariance and indicates whether the construct and the item descriptions of an instrument are invariant across time (Chang, Wu, Chen, Wang, & Lin, 2014; Su, Yang, & Lin, 2018). Because individuals always experience different life events and go through different life stages, this may cause them to interpret scale item descriptions differently across time. More specifically, because of different life experiences, individuals may differently interpret such items in scales such as the SABAS, BSMAS, and IGDS-SF9 across time. It should also be noted that a time criterion in the diagnosis of online gaming disorder (i.e., over a period of 12 months or more) was recommended in both the appendix of the DSM-5 (where IGD was listed as a tentative disorder; American Psychiatric Association, 2013) and in the addictive behaviors section of the latest (eleventh) edition of the International Statistical Classification of Diseases and Related Health Problems (ICD-11) (where it was listed as gaming disorder [predominantly online]; Van den Brink, 2017). Thus, if time invariance of any of the instruments is not supported, it may not be stable enough to assess the risk of addiction for young adults. Using the techniques of confirmatory factor analysis (CFA), time invariance of psychometric instruments (in this case the SABAS, BSMAS, and IGDS-SF9) can be evaluated for the equivalence of their factor loadings, item intercepts, and construct across time (Motl & Distefano, 2002).

Another important psychometric property has not been thoroughly examined for these three instruments is reproducibility, which indicates whether attributes can be assessed in a consistent manner when administered on several occasions to the target population (Su et al., 2018). Satisfactory reproducibility of the instrument can lead to a more precise assessment alongside a better ability of detecting changes concerning research or clinical practice (Beckerman et al., 2001; Hopkins, 2000). Additionally, given that *changes* over time can be separated into two components (*mean difference* and *correlation*), reproducibility can be presented as relative reliability or absolute reliability. More specifically, good reproducibility indicates that (i) the measure score at baseline is related to the measure score at follow-up (relative reliability; e.g., test-retest reliability using intraclass correlation coefficient [ICC] or Pearson correlation) and (ii) the mean measure score is the same across time (absolute reliability; e.g., standard error of measurement [SEM] and smallest real difference [SRD]). Therefore, the relative reliability helps understand whether an instrument has high correlation in its baseline and follow-up measures without considering individual differences.

On the other hand, absolute reliability helps understand the variances that are not caused by individual differences, or so-called measurement errors of an instrument (Chen et al. 2007; Su, Ng, Yang, & Lin, 2014). It should also be noted that SEM represents the absolute reliability for a group whereas SRD represents the reliability for a single individual. Therefore, SEM indicates how the ratings of the entire sample at baseline agree with their ratings at the follow-up measure. SRD indicates how the rating of an individual in the sample at baseline agrees with their rating at follow-up some time later. Given that SEM and SRD provide information on measurement errors, a lower SEM and SRD indicate better reliability.

To the best of the present authors' knowledge, only one Persian validation study has demonstrated reproducibility of the IGDS-SF9 using test-retest reliability (a type of relative reliability) among 12- to 19-year-old Iranian adolescents over a two-week interval (Wu et al., 2017). However, no previous studies have applied absolute reliability to provide meaningful insight for clinical practice across two time periods. Additionally, the reported reproducibility of these instruments has only been tested over a short interval (e.g., two weeks in Wu et al., 2017). Whether such reproducibility exists over a longer time (e.g., three months) is at present unclear.

The purposes of the present study were (i) to examine the time invariance of the SABAS, BSMAS, and IGDS-SF9 for Chinese university students, and (ii) to evaluate the reproducibility, including relative and absolute reliabilities, of the three instruments across three months. It was hypothesized that the SABAS, BSMAS, and IGDS-SF9 would be time invariant and would have satisfactory relative and absolute reliabilities.

Methods

Participants and procedure

After receiving approval from the ethics committee of Hong Kong Polytechnic University, the authors designed an online survey using *Google Forms*. The online survey began with details of the study's purpose and requirements followed by an informed consent form. If the participants did not give their informed consent to participate, they were unable to complete the online survey. Those who agreed to participate were asked to provide demographic information and three psychometric scales concerning risk of smartphone addiction, social media addiction, and internet gaming disorder (i.e., SABAS, BSMAS, and IGDS-SF9).

A hyperlink and a QR code were created for students to log onto *Google Forms* and to participate in the survey. Through the assistance of several research assistants and teaching faculties, the survey link and QR code were disseminated in the university lectures or to students' email addresses between March and June 2018 for baseline assessment. The inclusion criteria of eligible participants were: (i) being aged 18 years or above; (ii) owing any type of smartphone; (iii) having access to the internet; and (iv) being capable of understanding written Chinese in traditional characters. The only exclusion criterion was having a mental health problem (e.g., mood disorders). Additionally, each participant was asked to provide their smartphone number and a frequently used email account to (a) ensure that no respondents completed the survey twice or more at baseline; and (b) contact them for the follow-up participation three months after the baseline.

Following this process, a total of 306 students from Hong Kong and 336 students from Taiwan completed the baseline assessment; 156 Hong Kong students and 118 Taiwan students completed the follow-up survey. Moreover, two Hong Kong students were removed from the analyses because they wanted their data removed from the follow-up study. They clearly indicated that their data could be used in a previously related study (i.e., Leung et al., 2019) but not in the present study. More specifically, the previous study used baseline data to establish the measurement invariance of the three studied instruments (i.e., SABAS, BSMAS, and IGDS-SF9) across Hong Kong and Taiwan university students (Leung et al., 2019). Finally, the present study used baseline and follow-up data from 304 Hong Kong students and

336 Taiwan students for analyses because (i) two Hong Kong students were removed because they did not want their data be used in this present study; and (ii) the lost to follow-up information was estimated using full information maximum likelihood (FIML) estimator.

Instruments

Smartphone Application-Based Addiction Scale (SABAS). The SABAS (Csibi et al., 2018) utilizes the six criteria of the addiction components model (salience, mood, modification, tolerance, withdrawal conflict and relapse) as the basis for its six items and assesses the single construct of being at risk of addiction to smartphone applications. All the items are rated using a six-point Likert type scale (1=*strongly disagree* and 6=*strongly agree*), and a higher score in the SABAS indicates a higher risk of developing an addiction to smartphone applications. Additionally, the psychometric properties of the SABAS have been supported in English (Csibi et al., 2018), Hungarian (Csibi et al., 2016), Persian (Lin et al., 2018) and Hong Kong samples (Yam et al., 2018). The internal consistency of the SABAS was acceptable in the present study (α=0.767 and ω=0.773 at baseline; α=0.782 and ω=0.800 at follow-up).

Bergen Social Media Addiction Scale (BSMAS). The BSMAS also adopts the six criteria of the addiction components model (Griffiths, 2000; 2005) to assess the risk of social media addiction (Andreassen et al., 2016). More specifically, there are six items in the BSMAS that assess the using of social media over the past year. All the items are rated using a five-point Likert type scale (1=*very rarely* and 5=*very often*). A higher BSMAS score suggests a higher risk of developing an addiction to social media with a cutoff score (19 out of 30) proposed recently to indicate problematic use of social media in a large nationally representative study of nearly 6000 Hungarian adolescents (Bányai et al., 2017). The psychometric properties of the BSMAS have previously been validated in English (Andreassen et al., 2016), Italian (Monacis et al., 2017), Persian (Lin, Broström, Nilsen, Griffiths, & Pakpour, 2017), Portuguese (Pontes, Andreassen, & Griffiths, 2016), and Hong Kong samples (Yam et al., 2018). The internal consistency of the BSMAS was satisfactory in the present study (α=0.818 and ω=0.818 at baseline; α=0.858 and ω=0.859 at follow-up).

Internet Gaming Disorder Scale-Short Form (IGDS-SF9). The IGDS-SF9 comprises the nine internet gaming disorder criteria described in the latest (fifth) edition of the DSM-5 (American Psychiatric Association, 2013) to assess the risk of developing IGD (Pontes & Griffiths, 2015). All the nine items are rated using a five-point Likert type scale (1=*never* and 5=*very often*), and a higher score on the IGDS-SF9 indicates a higher risk of developing IGD. The IGDS-SF9 has previously been validated with promising psychometric properties in English (Pontes & Griffiths, 2015; Pontes, Stavropoulos, & Griffiths, 2017), Portuguese (Pontes & Griffiths, 2016), Italian (Monacis, Palo, Griffiths, & Sinatra, 2016), Persian (Wu et al., 2017), Polish (Schivinski, Brzozowska-Woś, Buchanan, Griffiths, & Pontes, 2018), Albanian (de Palo et al., 2018), Turkish (Arıcak, Dinç, Yay, & Griffiths, 2018; Evren et al., 2018), and Hong Kong samples (Yam et al., 2018). The internal consistency of the IGDS-SF9 was excellent in the present study (α=0.916 and ω=0.918 at baseline; α=0.920 and ω=0.923 at follow-up).

Data analysis

Descriptive analyses were first used to understand participant characteristics. Then, three nested models in the CFA were constructed to examine whether the SABAS, BSMAS, and IGDS-SF9 were time invariant across three months in university students. All the CFAs were estimated using diagonally weighted least square (DWLS) method with missing values imputed by the FIML method. The degree of missing data was 38% (241 out of 640 did not complete follow-up survey). Additionally, it was justified that the missing data can be viewed as missing at random with the following nonsignificant differences between those completed survey twice and those who completed it once: age ($t=-0.51$; $p=0.22$), hours spent on using smartphone per day (t=0.33; p=0.75), hours spent on using social media per day (t=0.41; p=0.68), and hours spent on gaming per day (t=0.43; p=0.67).

Because measurement invariances of the SABAS, BSMAS, and IGDS-SF9 have been supported across Hong Kong and Taiwan people in Study Part A (see Leung et al. [2019], Table 4, for detailed information), all the 640 participants were included in the analyses. In terms of the nested models, Model 1 is a configural model; Model 2 is a model with factor loadings constrained as equal across time; and Model 3 is a model with factor loadings and item intercepts constrained as equal across time. Before the three nested models were tested, it was ensured that the configural model had acceptable data-model fit in the following indices: comparative fit index (CFI) > 0.9, root mean square of approximation (RMSEA) < 0.1, and SRMR (standardized root mean square residual) < 0.08 (Browne & Cudeck, 1993; Lin, 2018; Pakpour et al., 2018). The modification index was used when the configural model did not have acceptable fit.

In the time invariance testing, a nonsignificant χ^2 difference test suggests measurement invariance. However, ΔCFI, ΔRMSEA, and ΔSRMR were used to replace the χ^2 difference test because χ^2 is too sensitive to detect non-invariance in a large sample (Chang et al., 2014). More specifically, time invariance is supported for factor loadings if ΔCFI > 0.01, ΔRMSEA < 0.015, and ΔSRMR < 0.03; and supported for item intercepts if ΔCFI > 0.01, ΔRMSEA < 0.015, and ΔSRMR < 0.01 (Chen, 2007; Lin et al., 2013).

Relative reliability was examined using the intraclass correlation coefficient (ICC), where a value >.75 was considered excellent (Cheng, Luh, Yang, Su, & Lin, 2016). The ICC was calculated using one-way random effects with absolute agreement and multiple measurements (i.e., ICC (1, k). More specifically, the formula of the ICC is: mean square for rows minus mean square for residual sources of variance; then, divided by mean square for rows. Absolute reliability was examined using standard error of measurement (SEM) and smallest real difference (SRD) with the equations are: SEM= SD of the test-retest mean score × √(1 − ICC); SRD= 1.96 × SEM × √2. Moreover, SRD% was calculated using SRD/mean test-retest score with an SRD% < 30% is in anticipation (Chen, Chen, Hsueh, Huang, & Hsieh, 2009).

Finally, the convergent and divergent validity of follow-up SABAS, BSMAS, and IGDS-SF9 scores were explored using a Pearson correlation (or Spearman correlation, which was used for correlation with time spent on gaming at baseline). More specifically, follow-up SABAS, BSMAS, and IGDS-SF9 scores were correlated with the following variables: time spent on smartphone/social media/gaming at baseline, the three instrument scores at baseline, and the three instrument scores at follow-up.

The parametric statistics used in the present study were supported by the near normal distributions among the tested variables: skewness = -0.63 to 0.58 for SABAS, -0.38 to 0.73 for BSMAS, 0.21 to 2.41 for IGDS-SF9, 1.32 for time spent on smartphone at baseline, and 1.48 for time spent on social media at baseline; kurtosis = -0.94 to -0.16 for SABAS, -0.69 to 0.27 for BSMAS, -1.06 to 6.74 for IGDS-SF9, 2.86 for time spent on smartphone at baseline, and 2.56 for time spent on social media at baseline. However, time spent on gaming was not normally distributed (skewness = 4.02 and kurtosis = 24.44). The demographic data and relative reliability were analyzed using SPSS 23.0 (IBM Corp., Armonk, NY, USA) while absolute reliability was computed using Microsoft EXCEL 2010. Nested models of CFA were carried out using LISREL 8.8 (Scientific Software International, Lincolnwood, IL, USA).

Results

Table 1 presents the participants' characteristics at baseline, where Taiwan students were significantly younger than Hong Kong students. Additionally, Taiwan students had more hours on using social media and gaming as compared with their Hong Kong counterparts. Moreover, the Taiwan sample comprised more males than the Hong Kong sample. Almost no students were current smokers (1.6% in total). The distribution of the item scores for each scale is presented in Table 2. Moreover, based on the cutoff (19 out of 30) suggested by Bányai et al. (2017), 10.2% of Hong Kong participants (31 out of 304) and 21.7% of Taiwanese participants (73 out of 336) were at risk of addiction to social media at baseline.

(Insert Tables 1 and 2 here)

SABAS, BSMAS, and IGDS-SF9 all had satisfactory fit indices in the configural model. Therefore, measurement invariance of all scales was examined without using the modification index. After ensuring the configural models for the three scales, results of the nested models demonstrated that the SABAS, BSMAS, and IGDS-SF9 were time invariant (Table 3).

(Insert Table 3 here)

Table 4 additionally shows that the SABAS, BSMAS, and IGDS-SF9 had satisfactory relative reliability across three months. Also, absolute reliability of the three instruments was satisfactory as indicated by their small SRD%. Additionally, the convergent and divergent validity of the three instruments at follow-up were partially supported by the reported correlations in the coefficient matrix (Table 5). For example, time spent on smartphone had higher correlation with SABAS score ($r = 0.13$) than with IGDS-SF9 score ($r < 0.01$), and time spent on gaming had higher correlation with IGDS-SF9 score ($r = 0.28$) than with SABAS score ($r = 0.10$) and with BSMAS score ($r = -0.07$).

(Insert Tables 4 and 5 here)

Discussion

To the best of the present authors' knowledge, this is the first study to examine the properties of time invariance and long-term reproducibility of three commonly used and well validated instruments relating to problematic online use (i.e., the Smartphone Application-Based Addiction Scale [SABAS], Bergen Social Media Addiction Scale

[BSMAS], and the nine-item Internet Gaming Disorder Scales-Short Form [IGDS-SF9]). Findings from the present study are in concurrence with most of the previous literature (e.g., Bányai et al., 2017; Csibi et al., 2018; Pontes & Griffiths, 2015; Yam et al., 2018) that the three instruments are psychometrically sound and robust. More specifically, the results of present study demonstrated again that SABAS, BSMAS, and IGDS-SF9 all have a single-factor structure. The present findings further suggest that the single-factor structure is invariant across three months among young adults. Apart from the factorial structure, the present study's findings support the contemporary concepts concerning specific online addictions (Brand et al., 2014; Davis, 2001; Griffiths, 1998, 2000; Montag et al., 2015; Sha et al., 2018). More specifically, the correlations among the follow-up SABAS, BSMAS, and IGDS-SF9 were not highly correlated (r = .06 to .42).

Additionally, based on self-report, the participants in the present study spent more time on smartphones and social media than a recent largescale investigation (N=2418; Montag et al., 2015). On average, the participants here spent 5.1 hours daily on smartphone and 3.0 hours daily on social media, while the participants in Montag et al.'s (2015) study spent 2.7 hours on smartphones and 0.5 hours on social media. The differences of time spent on smartphone and social media in present study and the findings from Montag et al. (2015) may due to the different measures used to assess time. Montag et al. used objective time measures (via smartphone application) as opposed to the self-reports in the present study. The self-reported time may help explain the low correlations between time on smartphones, social media, and gaming, and the scores on the SABAS, BSMAS, and IGDS-SF9 in the present study.

Given that there are no studies examining time invariance and long-term reproducibility for the three instruments, future studies are needed to investigate whether time invariance and long-term reproducibility exist in other language versions of the SABAS, BSMAS, and

IGDS-SF9. With the evidence of time invariance established for the three instruments, healthcare providers and researchers can ensure that they are assessing the same concepts across time (Chang et al., 2014; Su et al., 2018). Thus, the comparisons between baselines and follow-ups are meaningful. For example, when a healthcare provider wants to evaluate a program on IGD reduction, the healthcare provider should use the same tool (e.g., IGDS-SF9) at least twice (baseline and post-intervention assessment) to determine whether the intervention is effective or not. If the IGDS-SF9 does not have good properties concerning time invariance, the participants may have different interpretations on the IGDS-SF9 at baseline and at the post-intervention assessment. As a result, absolute efficacy of the program cannot be conclusively established.

Although the literature does not have information on the long-term reproducibility of the three instruments, information on short-term relative reproducibility has been reported for Persian IGDS-SF9. More specifically, test-retest reliability using Pearson correlation in a two-week interval was 0.87 for Persian (Wu et al., 2017), which is comparable to the present finding (where test-retest reliability using ICC was 0.94). The present findings indicated that the other two instruments (SABAS and BSMAS) also shared satisfactory test-retest reliability using ICC (0.82 and 0.85). The present findings further extend the satisfactory relative reproducibility to acceptable absolute reproducibility (SRD%=28.1 for SABAS; 29.4 for BSMAS; and 23.8 for IGDS-SF9). In addition, the SEM and SRD values reported in the present study indicate the potential measurement error in a three-month retest. More specifically, SEM indicates the error for a sample and SRD indicates the error for an individual. For example, according to the present results of the SABAS scores, the SEM and SRD were 0.35 and 0.96, respectively. Therefore, changes of more than 0.35 in a sample and 0.96 points in an individual seem not to be attributable to chance variation or measurement error (Su et al., 2014; 2018).

There are some limitations in the present study. First, the present study did not collect any data regarding when the participants first began engaging in gaming, social media use, or smartphone use. The longer they engaged in these online activities might strengthen their risk of addiction, and result in higher scores on the three instruments examined. Second, the information concerning exclusion criteria used in this present study was collected via self-reports. Thus, it is unclear whether any of the participants had hidden any psychiatric diagnoses in order to participate in the present study. Consequently, the present findings cannot totally exclude the influences of hidden psychiatric comorbidity. Third, the results of the present study have limited generalizability because only young adults (and majority being from one university) were recruited. Whether the time invariance and good reproducibility found in the present study cannot necessarily be generalized to other age groups (e.g., retired people, high school students). Fourth, the self-report nature of the present study's data suffers from well-known biases including memory recall and social desirability (Yam et al., 2018). Future studies could consider using a mobile behavioral tracking app to collect objective measures of internet and/or smartphone use (Lin et al., 2015).

Fifth, the present study did not collect any information regarding life events that might have had a large influence on the participants' problematic behaviors (e.g., receiving psychological treatment) between baseline and follow-up assessments. Therefore, the results of reproducibility might be jeopardized due to the effects of the unknown events. Nevertheless, the reproducibility was very good in this present study; therefore, the impacts of life events were likely to have been mild. Sixth, not utilizing formal measures of psychiatric problems such as depression and anxiety is another limitation because the present study was unable to test the convergent validity of the three instruments. Nevertheless, the correlations outlined in Table 5 provide some evidence for the convergent and divergent validity of the three instruments. Finally, the time-invariant findings can only be generalized to those without a diagnosis of mental problem because this was one of the exclusion criteria. Given that generalized internet addiction is associated with various psychiatric or mental health problems (e.g., Rücker et al., 2015; Sariyska et al., 2015; Weinstein et al., 2015), the exclusion criterion excluded those with potentially high symptom severity. Future studies should therefore also recruit individuals with diagnosed mental health problems to corroborate the time-invariant findings for the three scales in the present study.

The present study demonstrated that the short, valid, reliable, and easy-to-use Chinese SABAS, BSMAS, and IGDS-SF9 can be used for longer-term assessment. More specifically, they have strong properties concerning time invariance and reproducibility. Therefore, using the three instruments in a three-month pre- and post-test is acceptable. Healthcare providers may further use the three instruments to regularly screen online related-addiction risk in a Chinese youth population. Additionally, the three instruments may be feasible in examining program effects on reducing online-related symptoms in young adults.

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Table 1. Participant characteristics at baseline

Characteristics	Taiwan sample (*n* = 336)	Hong Kong sample (*n* = 304)	χ^2 or t (*p*)
	Mean±SD or n (%)	Mean±SD or n (%)	
Age (years)	20.51±1.22	24.18±4.92	12.66 (<0.01)
Gender (Male)	167 (49.7)	99 (32.6)	19.30 (<0.01)
Current smoker (Yes)	4 (1.2)	6 (2.0)	0.64 (0.42)
Hours spent on using smartphone per day	5.07±2.75	5.21±3.54	-0.55 (0.58)
Hours spent on using social media per day	3.26±2.47	2.80±2.39	2.39 (0.02)
Hours spent on gaming per day	1.32±2.06	0.98±1.57	2.33 (0.02)

Table 2. Distribution of the item scores among Smartphone Application-Based Addiction Scale (SABAS), Bergen Social Media Addiction Scale (BSMAS), and Internet Gaming Disorder Scale-Short Form (IGDS-SF9) at baseline (*N* = 640)

	N (%)					
	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6
SABAS						
Item 1	19 (3.0)	54 (8.4)	61 (9.5)	205 (32.0)	125 (19.5)	176 (27.5)
Item 2	142 (22.2)	213 (33.3)	89 (13.9)	134 (20.9)	24 (3.8)	38 (5.9)
Item 3	42 (6.6)	95 (14.8)	95 (14.8)	221 (34.5)	84 (13.1)	103 (16.1)
Item 4	23 (3.6)	104 (16.3)	106 (16.6)	222 (34.7)	76 (11.9)	109 (17.0)
Item 5	79 (12.3)	182 (28.4)	149 (23.3)	155 (24.2)	44 (6.9)	31 (4.8)
Item 6	55 (8.6)	187 (29.2)	182 (28.4)	143 (22.3)	39 (6.1)	34 (5.3)
BSMAS						
Item 1	59 (9.2)	125 (19.5)	248 (38.8)	151 (23.6)	57 (8.9)	—
Item 2	69 (10.8)	191 (29.8)	245 (38.3)	107 (16.7)	28 (4.4)	—
Item 3	190 (29.7)	260 (40.6)	141 (22.0)	41 (6.4)	8 (1.3)	—
Item 4	136 (21.3)	251 (39.2)	182 (28.4)	62 (9.7)	9 (1.4)	—
Item 5	207 (32.3)	244 (38.1)	153 (23.9)	30 (4.7)	6 (0.9)	—
Item 6	156 (24.4)	239 (37.3)	190 (29.7)	37 (5.8)	18 (2.8)	—
IGDS-SF9						
Item 1	166 (25.9)	251 (39.2)	143 (22.3)	55 (8.6)	25 (3.9)	—
Item 2	252 (39.4)	261 (40.8)	103 (16.1)	23 (3.6)	1 (0.2)	—
Item 3	214 (33.4)	246 (38.4)	128 (20.0)	41 (6.4)	11 (1.7)	—
Item 4	229 (35.8)	271 (42.3)	96 (15.0)	40 (6.3)	4 (0.6)	—
Item 5	279 (43.6)	246 (38.4)	90 (14.1)	23 (3.6)	2 (0.3)	—

Item 6	300 (46.9)	234 (36.6)	70 (10.9)	27 (4.2)	9 (1.4)	—
Item 7	398 (62.2)	166 (25.9)	61 (9.5)	12 (1.9)	3 (0.5)	—
Item 8	182 (28.4)	166 (25.9)	214 (33.4)	61 (9.5)	17 (2.7)	—
Item 9	417 (65.2)	165 (25.8)	39 (6.1)	13 (2.0)	6 (0.9)	—

Table 3. Data-model fit indices and model comparisons for the Smartphone Application-Based Addiction Scale (SABAS), Bergen Social Media Addiction Scale (BSMAS), and Internet Gaming Disorder Scale-Short Form (IGDS-SF9) (*N* = 640)

Model #	χ^2	*df*	CFI	RMSEA	SRMR	Model Comparisons	$\Delta\chi^2$	Δdf	ΔCFI	ΔRMSEA	ΔSRMR
SABAS											
M1	180.693*	47	0.983	0.0667	0.0450	--	--	--	--	--	--
M2	211.139*	52	0.980	0.0692	0.0515	M2-M1	30.446*	5	-0.0030	0.0025	0.0065
M3	219.253*	57	0.980	0.0667	0.0515	M3-M2	8.114	5	0.0000	-0.0025	0.0000
BSMAS											
M1	308.511*	47	0.976	0.0933	0.0603	--	--	--	--	--	--
M2	314.882*	52	0.976	0.0889	0.0627	M2-M1	6.371	5	0.0000	-0.0044	0.0024
M3	330.723*	57	0.975	0.0866	0.0627	M3-M2	15.841*	5	-0.0010	-0.0023	0.0000
IGDS-SF9											
M1	556.783*	125	0.992	0.0735	0.0475	--	--	--	--	--	--
M2	597.779*	133	0.991	0.0740	0.0568	M2-M1	40.996*	8	-0.0010	0.0005	0.0093
M3	622.772*	141	0.991	0.0731	0.0568	M3-M2	24.993*	8	0.0000	-0.0009	0.0000

df = degree of freedom; CFI = comparative fit index; RMSEA = root mean square of approximation; SRMR = standardized root mean square residual.

M1: Configural model; M2: All factor loadings were invariant between test and retest; M3: All factor loadings and item intercepts were invariant between test and retest.

* $p < .05$

Table 4. Reliability of the Smartphone Application-Based Addiction Scale (SABAS), Bergen Social Media Addiction Scale (BSMAS), and Internet Gaming Disorder Scale-Short Form (IGDS-SF9) (*N* = 640)

	Baseline	Follow-up	*p*-value	ICC	SEM	SRD	SRD%
	Mean (SD)	Mean (SD)					
SABAS	3.46 (0.92)	3.36 (0.71)	<.001	.82	0.35	0.96	28.2
BSMAS	2.41 (0.71)	2.48 (0.61)	<.001	.86	0.25	0.68	28.0
IGDS-SF9	1.88 (0.70)	1.86 (0.61)	.09	.94	0.16	0.44	23.8

ICC = intraclass correlation coefficient; SEM=standard error of measurement; SRD=smallest real difference.

Table 5. Correlation of follow-up Smartphone Application-Based Addiction Scale (SABAS), Bergen Social Media Addiction Scale (BSMAS), and Internet Gaming Disorder Scale-Short Form (IGDS-SF9) with relevant criteria (*N* = 640)

	r (*p*-value)		
	Follow-up SABAS	Follow-up BSMAS	Follow-up IGDS-SF9
1. Time on smartphone[a]	.13 (.001)	.10 (.014)	.00 (.992)
2. Time on social media[a]	.09 (.030)	.09 (.019)	-.10 (.011)
3. Time on gaming[a, b]	.10 (.015)	-.07 (.071)	.28 (<.001)
4. Baseline SABAS	.78 (<.001)	.32 (<.001)	.27 (<.001)
5. Follow-up SABAS	--	.42 (<.001)	.26 (<.001)
6. Baseline BSMAS	.40 (<.001)	.72 (<.001)	.06 (.108)
7. Follow-up BSMAS	.42 (<.001)	--	.08 (.050)
8. Baseline IGDS-SF9	.26 (<.001)	.10 (.009)	.85 (<.001)
9. Follow-up IGDS-SF9	.26 (<.001)	.06 (.108)	--

[a] Measured at baseline

[b] Analyzed using Spearman correlation.

- Smartphone addiction, social media addiction, and internet gaming disorder are specific internet-related disorders
- Psychometrically robust instruments have been developed for these specific disorders
- The reproducibility of these scales has only been examined over a short period of time
- Time invariance of three scales were tested over a 3-month period
- The three scales had satisfactory reproducibility with little measurement noise.