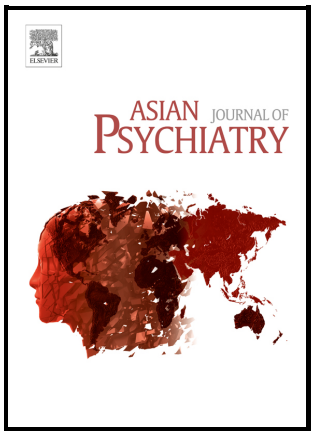

Psychometric properties and development of the Chinese versions of Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A)Short title: Chinese versions of gaming disorder tools

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PII: S1876-2018(23)00194-6

DOI: https://doi.org/10.1016/j.ajp.2023.103638

Reference: AJP103638

To appear in: *Asian Journal of Psychiatry*

Received date: 30 December 2022
Revised date: 21 May 2023
Accepted date: 21 May 2023

Please cite this article as: I-Hua Chen, Yen-Ling Chang, Yung-Ning Yang, Ya-Ching Yeh, Daniel Kwasi Ahorsu, Samuel Adjorlolo, Carol Strong, Yi-Ping Hsieh, Po-Ching Huang, Halley M. Pontes, Mark D. Griffiths and Chung-Ying Lin, Psychometric properties and development of the Chinese versions of Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A)Short title: Chinese versions of gaming disorder tools, *Asian Journal of Psychiatry,* (2023) doi:https://doi.org/10.1016/j.ajp.2023.103638

Psychometric properties and development of the Chinese versions of Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A)

Short title: Chinese versions of gaming disorder tools

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Abstract

Currently, two instruments have been developed using the 11th revision of the International Classification of Diseases (ICD-11) criteria for Gaming Disorder (GD): the Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A). The present study validated both GDT and GADIS-A among a large sample of Chinese emerging adults. Via

online survey, 3,381 participants (56.6% females; mean age = 19.56 years) completed the Chinese versions of the GDT, GADIS-A, Internet Gaming Disorder-Short Form (IGDS9-SF), and Bergen Social Media Addiction Scale (BSMAS). Confirmatory factor analysis was used to examine the factor structure of the Chinese GDT and GADIS-A. Pearson correlations were computed to examine the convergent validity (with IGDS9-SF) and divergent validity (with BSMAS) of the Chinese GDT and Chinese GADIS-A. The GDT had a unidimensional structure, which was invariant across sex and disordered gaming severity subgroups. The GADIS-A had a two-factor structure, which was also invariant across gender and gaming severity subgroups. Both GDT and GADIS-A had significant associations with both IGDS9-SF and with BSMAS. Both Chinese GDT and GADIS-A are valid instruments to assess GD among emerging adults in mainland China, enabling healthcare providers to adopt these tools in their efforts to prevent and examine GD severity among Chinese youth.

Keywords: Gaming Disorder Test; Gaming Disorder Scale for Adolescents; gaming disorder; gaming; internet; psychometrics; emerging adults

1. Introduction

After the American Psychiatric Association (APA) proposed Internet Gaming Disorder (IGD) as a tentative disorder in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; APA, 2013), the World Health Organization (WHO) formally included Gaming Disorder (GD) in the eleventh revision of the International Classification of Diseases (ICD-11; ICD-11, 2022; WHO, 2019). In the DSM-5, IGD is defined using nine diagnostic criteria (e.g., preoccupation with gaming) (APA, 2013). In the ICD-11, three diagnostic criteria have been proposed for GD (e.g., an impaired control over gaming) (WHO, 2019).

From the two aforementioned disordered gaming diagnostic frameworks provided in the

DSM-5 (on IGD) and ICD-11 (on GD), it can be observed that the two disorders (i.e., IGD and GD) shared some similarities and differences at the diagnostic level (see Maldonado-Murciano, 2022; Montag et al., 2019; Pontes et al., 2022). For example, both diagnostic frameworks acknowledge the importance of how gaming behaviors may impact daily activities, social relationships, and the ability to quit gaming. Whereas, different numbers of diagnostic criteria have been proposed for IGD and GD (Pontes et al., 2021), which may indicate that IGD-based instruments cannot be used for GD assessment due to differing key diagnostic criteria. Some evidence further shows that GD appears to have a higher diagnostic threshold than IGD with (Jo et al., 2019; Ko et al., 2019). It can be thus concluded that instruments assessing IGD may not be totally suitable to assess GD using the criteria proposed in the WHO framework (Paschke et al., 2020, 2021; Pontes et al., 2021).

Currently, over 30 instruments have been developed to assess problematic gaming, although no consensus has been reached yet regarding which instruments present superior psychometric properties compared to others (see King et al., 2020). Unlike the IGD instruments, to the best of the present authors' knowledge, only six instruments have been developed to assess GD using the WHO framework: Gaming Disorder Test (GDT) (Pontes et al., 2021), Gaming Disorder Scale for Adolescent (GADIS-A) (Paschke et al., 2020), Gaming Disorder Scale for Parents (GADIS-P) (Paschke et al., 2021), nine-item short screening test for ICD-11 gaming disorder (GAMES test) (Higuchi et al., 2021), Gaming Disorder and Hazardous Gaming Scale (GDHGS) (Balhara, 2022), and the Assessment of Criteria for Specific Internet-use Disorders (ACSID-11) (Müller et al., 2022).

The present study focuses on GDT and GADIS-A because both instruments are brief self-report measures (presenting with the benefits of easy administration and cost-effectiveness) based on the most recent and updated WHO framework. Moreover, a recent review study conducted by Karhulahti et al. (2021) reported that of all available

assessment tools for disordered gaming, the GDT was the only tool showing the highest level of validity in the operationalization of the assessment criteria for GD.

Although the GADIS-A was developed for children and adolescents (Paschke et al., 2020), the present authors consider that it is comparable to the GDT when assessing GD among emerging adults. More specifically, emerging adults, especially university students, still need support from their families and are still somewhat under parental control (and this is especially true for the present study's sample) (Chen-Bouck & Patterson, 2017; Jeong & Lim, 2021). Therefore, simultaneously examining the GDT and GADIS-A could be helpful for Chinese healthcare providers to decide which instrument to use when assessing GD among Chinese young adults. Moreover, both the GDT and GADIS-A are newly developed instruments and information regarding their psychometric properties remains insufficient.

The present study aimed to examine the psychometric properties of the Chinese GDT and GADIS-A among emerging adults in mainland China to provide further cross-cultural psychometric information concerning both instruments. More specifically, factor structure and measurement invariance (across gender and GD severity levels) of the two instruments were examined. Moreover, convergent validity (with an instrument assessing IGD) and divergent validity (with an instrument assessing social media addiction) and known-group validity (across gender and GD severity levels) were examined for both instruments. Validating both Chinese GDT and GADIS-A are needed because healthcare providers can use them to evaluate the GD severity of Chinese emerging adults. Moreover, due to the brevity of both the GDT and GADIS-A, the evaluation time could be cost-efficient. The potential users of GDT and GADIS-A in China are diverse, including healthcare providers, consultants, psychiatrists, psychologists, researchers, and mental health professionals.

2. Methods

2.1 Participants and procedure

Invitation letters were sent to the head of student affairs from 25 universities across 30 provinces and municipalities in mainland China. The invitation asked whether the universities were willing to distribute an online survey to their students. Nineteen universities agreed to participate, and they were provided with a hyperlink to the online survey. Data collection took place from August to October 2022. These 19 universities were from all major provinces in China, mainly from the central, southern, and eastern regions. A total of 3,381 college students provided an e-consent and completed the online survey. As all questions were required to be completed before answers could be uploaded in the online platform, there were no missing responses. The ethical approval of the online survey was obtained by the Institutional Review Board of the Jiangxi Psychological Consultant Association (IRB ref: JXSXL-2021-J99).

There are different approaches to develop psychometric instruments. For example, using the MEASURE approach which includes “Make the clear purpose”, “Establish framework”, “Articulate theory”, “Synthesize content for scale development”, “Use experts”, “Recruit participants”, and “Evaluate psychometric properties” (Kalkbrenner, 2021). However, when there are existing available instruments but not in the language needed, translation and validation of the instruments with cultural adaption into the target languages is needed (Beaton et al., 2000). Such validations can maximize the capability to carry out international comparisons for such instruments. Therefore, the present study adopted the translation procedure recommended from Maneesriwongul and Dixon (2004) to translate the GADIS-A (i.e., using independent forward translations, independent back translation, reconciliation, expert panel meeting, and cognitive interviewing). Following this, validation of both the GDT and GADIS-A was carried out by implementing the final step of the MEASURE approach (i.e., evaluate psychometric properties) using classical test theory.

2.2 Measures

Gaming Disorder Test (GDT). The GDT is a four-item instrument developed using the GD criteria proposed within the WHO framework (Pontes et al., 2021). The GDT items are scored using a five-point Likert scale and higher scores indicate greater severity of GD. The GDT has been validated as a unidimensional structure instrument in different language versions (Cakiroglu & Alnak, 2021; Cudo et al., 2022; Maldonado-Murciano et al., 2021; Montag et al., 2019; Wang & Cheng, 2020), including simplified written Chinese (Pontes et al., 2021). In the present study, the GDT was developed and validated in an online setting rather than an offline (in-person) setting.

Gaming Disorder Scale for Adolescents (GADIS-A). The GADIS-A is a 13-item instrument developed using the GD criteria proposed within the WHO framework (Paschke et al., 2020). The first nine items of the GADIS-A are grouped into two factors: cognitive behavioral symptoms (CBS; Items 1, 2, 4, and 5) and negative consequences (NC; Items 3, 6, 7, 8, 9). The last four items of the GADIS-A are additional questions asking time-related information on GD instead of using it to construct the factor structure in the GADIS-A. The first nine items of the GADIS-A are scored using a five-point Likert scale and higher scores indicate greater severity of GD. Item 10 on the GADIS-A is responded as '*not at all*', '*only on single days*', '*during longer periods*', or '*almost daily*'. Answering '*during longer periods*' or '*almost daily*' indicates endorsement of this criterion. The GADIS-A has been validated in the Russian language (Nazari et al., 2022). However, it is yet to be translated into simplified written Chinese and the authors of the present study used standardized translation procedures (i.e., independent forward translations, independent back translation, reconciliation, expert panel meeting, and cognitive interviewing) (Maneesriwongul and Dixon, 2004) to ensure the linguistic validity of the GADIS-A for its use among mainland Chinese people. In the present

study, the GADIS-A was developed and validated in an online setting rather than an offline (in-person) setting.

Bergen Social Media Addiction Scale (BSMAS). The BSMAS is a six-item instrument developed using the Griffiths' (2005) components model of addiction (Andreassen et al., 2016). The BSMAS items are scored using a five-point Likert scale and higher scores indicate a greater risk of social media addiction. The BSMAS has been validated as a unidimensional instrument in different languages (Chen et al., 2020b; Leung et al., 2020; Shin, 2022; Lin et al., 2017; Monacis et al., 2017; Tung et al., 2022; Yam et al., 2019; Yue et al., 2022), including simplified written Chinese (Chen et al., 2020a).

Internet Gaming Disorder-Short Form (IGDS9-SF). The IGDS9-SF is a nine-item instrument developed using the IGD criteria proposed within the APA framework (APA, 2013; Pontes and Griffiths, 2015). The IGDS9-SF items are scored using a five-point Likert scale and high scores indicate greater severity of IGD. The IGDS9-SF has been validated as a unidimensional structure instrument in different languages (Poon et al., 2021), including simplified written Chinese (Chen et al., 2020a). Moreover, the IGDS9-SF in the present study is appropriate for use in online surveys because prior evidence shows that the IGDS9-SF used in the present study was designed for online surveys with satisfactory psychometric properties (Chen et al., 2020a, Chen 2020b; Leung et al., 2020).

2.3 Data analysis

Both instruments' ceiling/floor effects (<20% is satisfactory) and internal consistency (using McDonald's ω; >0.7 is satisfactory) were examined. Afterward, confirmatory factor analysis (CFA) with a diagonally weighted least squares was used to examine the factor structure of the GDT (one-factor solution) and for the GADIS-A (two-factor solution). For the CFA, the following fit indices were used to examine if the tested factor structure was

supported: comparative fit index (CFI)>0.9, non-normed fit index (NNFI)>0.9, root mean square error of approximation (RMSEA)<0.08, and standardized root mean square residual (SRMR)<0.08 (Huang et al., 2023; Lin et al., 2019; Nadhiroh et al., 2022; Nejati et al., 2020).

Afterward, measurement invariance was examined using multigroup CFA (MGCFA). In MGCFA, nested models (i.e., configural model, metric invariance model, and scalar invariance model) were compared using differences in CFI (ΔCFI), RMSEA (ΔRMSEA), and SRMR (ΔSRMR). The configural model does not constrain any factor loadings or item intercepts across subgroups, while the metric invariance model constrains factor loadings but not item intercepts as equal across subgroups. The scalar invariance model constrains both factor loadings and item intercepts as equal across subgroups (Cheung and Rensvold, 2002). When ΔCFI>-0.01 together with ΔRMSEA<0.015 and ΔSRMR<0.03, factor loading of the factor structure is viewed as invariant across subgroups. When ΔCFI>-0.01 together with ΔRMSEA<0.015 and ΔSRMR<0.01, item intercepts of the factor structure are viewed as invariant across subgroups (Chen et al., 2022; Chirawat et al., 2022; Rutkowski & Svetina, 2014). The subgroups tested in the present study included (i) gender (male vs. female); (ii) gaming hours (< 2 hours, 2-5 hours, and > 5 hours); (iii) disordered gaming severity (<32 points of IGDS9-SF score *vs.* ≥32 points of IGDS9-SF score) (Qin et al., 2020).

Apart from testing the factor structure of the GDT and GADIS-A, their convergent and divergent validity was assessed using Pearson correlations with two different external criterion measures (i.e., BSMAS and IGDS9-SF). More specifically, GDT and GADIS-A assess the concept (i.e., problematic gaming) more similar to the concept assessed by IGDS9-SF but not BSMAS (BSMAS assesses the concept of social media addiction). Therefore, it was expected that the GDT and GADIS-A would have stronger correlations with IGDS9-SF (convergent validity) and weaker correlations with BSMAS (divergent validity). Known-group validity of the GDT and GADIS-A was tested using independent *t*-tests (for

gender and disordered gaming severity subgroups) or analysis of variance (ANOVA; for gaming hours subgroups). Effect size of Cohen's *d* (0.2 small effect; 0.5 medium effect; 0.8 large effect) was calculated following the independent *t*-tests; effect size of η^2 (0.01 small effect; 0.06 medium effect; 0.14 large effect) was calculated following the ANOVA (Cohen, 1988). Lastly, because some of the participants might not be regular gamers (i.e., do not play videogames daily), the aforementioned data analyses, except for known-group validity, were performed only comprising participants who played videogames daily again for sensitivity analysis.

The statistical software used in the present study included LISREL 8.8 (for CFA and MGCFA), IBM SPSS software (for analyses other than CFA and MGCFA).

3. Results

Table 1 presents the participants' characteristics. Regarding the psychometric properties of GDT and GADIS-A, both instruments had satisfactory internal consistency (McDonald's ω=0.90 for GDT and 0.91-0.96 for GADIS-A). Fit indices from CFA supported the one-factor solution for GDT (CFI=0.999, NNFI=0.997, RMSEA=0.040, SRMR=0.009) and the two-factor solution for the GADIS-A (CFI=0.997, NNFI=0.996, RMSEA=0.052, SRMR=0.032) (Table 2). The statistical properties regarding each item mean (SD) score, factor loadings (ranged 0.83-0.93 [GDT]; 0.77-0.95 [GADIS-A]), and item-total correlations (ranged 0.73-0.83 [GDT]; 0.72-0.89 [GADIS-A]) are reported in Table 3.

(Insert Tables 1 to 3 here)

Tables 4 and 5 showed that both GDT and GADIS-A were invariant across gender, number of gaming hours, and disordered gaming severity. Convergent and divergent validity of the GDT and GADIS-A was further supported by the stronger correlations with IGDS9-SF (r=0.66-0.67; p<0.01) and weaker correlations with BSMAS (r=0.42-0.44; p<0.01).

Moreover, both GDT and GADIS-A were associated with time spent gaming (r=0.24-0.28; p<0.01) but not time spent on social media (r=0.02-0.03; p=0.08-0.23) (Table 6). Sensitivity analysis showed similar findings when participants who were not regular gamers were excluded from the aforementioned analyses (Supplement Tables S2 to S6).

(Insert Tables 4 to 6 here)

Known-group validity of the GDT and GADIS-A was also supported. More specifically, male participants had higher scores on the GDT and GADIS-A than female participants (Cohen's d=0.48 and 0.44). Participants with a score ≥32 points on the IGDS9-SF had higher GDT and GADIS-A scores than those with scores <32 points (Cohen's d=1.76 and 1.59). Participants spending more time gaming had higher scores on the GDT and GADIS-A scores than those spending less time gaming (η^2=0.13 and 0.10) (see Table 7).

(Insert Table 7 here)

4. Discussion

The present study used a variety of psychometric testing methods to examine the reliability and validity of two newly developed instruments for disordered gaming based on the WHO framework for GD (i.e., GDT and GADIS-A). The findings indicated that the four-item GDT had a one-factor solution, which was invariant across gender and disordered gaming severity while the first nine items of the GADIS-A had a two-factor solution, which was also invariant across gender and disordered gaming severity. Apart from the factor structures and their measurement invariance, the present findings indicated that both the GDT and GADIS-A had good internal consistency, convergent and divergent validity (with IGDS9-SF and BSMAS), and known-group validity. Therefore, both GDT and GADIS-A could be useful to tackle the problematic gaming issues indicated in the literature (Alimoradi et al., 2019, 2022; Kamolthip et al., 2022a).

The findings reported in the present study's GDT are comparable with all prior GDT

studies (Cakiroglu and Alnak, 2021; Cudo et al., 2022; Maldonado-Murciano et al., 2021; Montag et al., 2019; Wang and Cheng, 2020). The unidimensional structure of the GDT indicates that the four items of this instrument are embedded in the same construct of GD as defined within the WHO framework. Moreover, the unidimensional structure of the GDT is invariant across gender and disordered gaming severity, indicating that the GDT can be used to compare different subgroups without severe measurement errors. After ensuring the invariance properties of the GDT, the present study compared GDT scores across these subgroups and found that males had significantly higher scores in the GDT than females. The significant differences between genders are aligned with prior evidence showing that males (as compared to females) have greater gaming problems (Su et al., 2020). Also, participants with more severe gaming problems (i.e., greater gaming time and higher IGDS9-SF score) had significantly higher scores on the GDT than those with less severe problems (i.e., less gaming time and lower IGDS9-SF score). Therefore, the GDT presented with satisfactory properties to help distinguish individuals with severe GD from those with mild GD.

Additionally, the GDT was found to be significantly associated with other instruments assessing online behavioral addictions (i.e., IGDS9-SF and BSMAS). The associations found between the GDT, IGDS9-SF, and BSMAS are similar to prior evidence showing the significant associations between the IGDS9-SF and BSMAS (Chen et al., 2020a, 2020b) given that all these instruments assess behavioral addictions that have been shown to be related in previous studies (Akbari et al., 2023; Pontes, 2017; Rozgonjuk et al., 2021).

The present findings of GADIS-A's psychometric properties are also comparable with two prior studies (Nazari et al., 2022; Paschke et al., 2020). The two-factor structure of the GADIS-A indicated that its first nine items are embedded in two dimensions of GD: one emphasizing consequences (i.e., negative consequences [NC]) and another emphasizing symptom (i.e., cognitive behavioral symptoms [CBS]). The two-factor structure of GADIS-A

is different from the unidimensional structure of GDT, although both instruments were developed based on the WHO framework for GD (WHO, 2019).

As the GDT contains only four items covering both symptoms and consequences proposed by the WHO framework, it is possible to integrate both symptoms and consequences into one underlying concept. In contrast, the GADIS-A has nine items for its structure. Therefore, these items can be separated into different underlying constructs. Indeed, prior studies have shown that a multidimensional instrument can be refined to be unidimensional when a short version is developed (Hammer and Toland, 2017; Lin et al., 2017). Although the GADIS-A had a different factor structure from the GDT, the GADIS-A shares strong psychometric properties with the GDT regarding its measurement invariance (across gender and disordered gaming severity), known-group validity (between gender and GD severity subgroups), and convergent and divergent validity (with IGDS9-SF and BSMAS). Although the GADIS-A was initially developed for children and adolescents (Nazari et al., 2022; Paschke et al., 2020), the present findings indicate that the GADIS-A is also applicable and valid to be used in Chinese emerging adults. Nevertheless, the average age of the present sample was 19 years, which indicate that the sample still comprises mostly teenagers and future research on young adults with an older age is needed.

Given the present study's findings, healthcare providers and researchers may consider using either the GDT and/or GADIS-A to assess GD severity levels among Chinese emerging adults. Moreover, both instruments were found to be satisfactory, therefore their psychometric robustness will not pose issues to healthcare providers or researchers investigating GD. Instead, their major considerations should focus on what to assess and the length of time available for its administration. While the GDT is more appropriate than GADIS-A to be an instrument for a busy clinical setting and large-scale epidemiological research due to its brevity (Chen et al., 2022; Saffari et al., 2022), the GADIS-A can help

provide more detailed information than the GDT regarding the issues of GD symptoms and negative consequences, particularly in clinical settings.

The present study has some limitations. First, the sample was recruited using convenience sampling and the representativeness of the present findings cannot be generalized to the entire mainland China population. Therefore, future studies with larger and more representative samples are needed so that individuals with a diverse background in the mainland China can be included. Second, the present study did not examine test-retest reliability for either the GDT and GADIS-A. Consequently, the reproducibility of the two instruments remains unclear. Consequently, future studies should examine if both GDT and GADIS-A have good test-retest reliability across a reasonable time period (e.g., two weeks to one month). Third, all the instruments used in the present study were self-report. Therefore, the present findings are subject to single-rater bias, social desirability bias, and recall bias. Future studies could use more objective measures (e.g., using smartphone apps to record the time spent on gaming) and clinician-rated measures (e.g., GDHGS) to reduce the problems of single-rater bias. Lastly, the present study tested the psychometric properties of the GDT and GADIS-A using data collected online. Therefore, it is unknown if the present study's psychometrics findings would be replicated if the data for the GDT and GADIS-A were collected in offline (in-person) settings. Therefore, future studies are needed to examine the psychometric properties of the GDT and GADIS-A in offline settings.

Acknowledgement

We thank the faculty members who helped distributing the online survey to the target participants. We also thank all the participants.

Funding

This research was supported in part by (received funding from) the Ministry of Science and

Technology, Taiwan (MOST 110-2410-H-006-115; MOST 111-2410-H-006-100), the Higher Education Sprout Project, the Ministry of Education at the Headquarters of University Advancement at the National Cheng Kung University (NCKU), and the 2022 Southeast and South Asia and Taiwan Universities Joint Research Scheme (NCKU 35).

Author contributions

Conceptualization: I-HC, Y-LC, J-SC, Y-CY, DKA, SA, CS, Y-PH, P-CH, HMP, MDG, C-YL; Data curation: I-HC, C-YL; Formal analysis: I-HC, Y-LC, J-SC, Y-CY; Funding acquisition C-YL, CS; Investigation: I-HC, Y-LC, J-SC, C-YL; Methodology: Y-CY, DKA, SA, CS, Y-PH, P-CH, HMP, MDG, C-YL; Project administration: I-HC, C-YL; Resources: I-HC, Y-LC, J-SC, C-YL; Software: I-HC, Y-LC, J-SC, DKA, SA, CS, Y-PH; Supervision: C-YL; Validation: I-HC, Y-LC, J-SC, Y-CY, DKA, SA, CS, Y-PH, P-CH, HMP, MDG; Visualization: I-HC, C-YL; Roles/Writing - original draft: I-HC, Y-LC, J-SC, C-YL; Writing - review & editing: Y-CY, DKA, SA, CS, Y-PH, P-CH, HMP, MDG, C-YL

Conflict of interest

All authors declare no conflicts of interest.

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Tables

Table 1. The characteristics of participants (*N*=3381)

	n (%)	Mean (*SD*)	Median (Q1, Q3)	Range
Age (years)		19.56 (1.59)	19 (19, 20)	16-38
Marital Status				
Single	3301 (97.6)			
Married	31 (0.9)			
Divorced or separated	49 (1.5)			
Gender				
Male	1469 (43.4)			
Female	1912 (56.6)			
Subject major				
Education	551 (16.3)			
Science	820 (24.3)			
Engineering	730 (21.6)			
Management	280 (8.3)			
Economics	193 (5.7)			
Literature	273 (8.1)			
Arts	238 (7.0)			
Medical Science	135 (4.0)			
Others	161 (4.7)			
Program				
Undergraduate	3353 (99.2)			
Postgraduate	28 (0.8)			
Internet use				
Time spent on smartphone (hours per day)		6.20 (4.68)	5.08 (3, 8.35)	0-23
Time spent on using social media (hours per day)		3.33 (3.74)	2.03 (1.02, 4.00)	0-23
Time spent on gaming (hours per day)		1.82 (3.03)	1.02 (0.02, 2.03)	0-23
Behavioral addiction				
BSMAS		14.19 (4.76)	14 (11, 18)	6-30
IGDS9-SF		18.10 (7.44)	18 (11, 24)	9-45

BSMAS = Bergen Social Media Addiction Scale; IGDS9-SF = Nine-item Internet Gaming Disorder Scale–Short-Form

Table 2. Psychometric properties of of the GDT and GADIS-A

	GDT	GADIS-A	Suggested cutoff
Ceiling effects (%)	15 (0.4)	20 (0.6) [entire GADIS-A]; 24 (0.7) [CBS]; 22 (0.7) [NC]	<20
Floor effects (%)	1087 (32.2)	916 (27.1) [entire GADIS-A]; 1000 (29.6) [CBS]; 1118 (35.1) [NC]	<20
Internal consistency (McDonald's ω)	0.90	0.96 [entire GADIS-A]; 0.91 [CBS]; 0.95 [NC]	>0.70
Confirmatory factor analysis			
χ^2 (df)	12.86 (2)	267.94 (26)	
CFI	0.999	0.997	>0.90
NNFI	0.997	0.996	>0.90
RMSEA	0.040	0.052	<0.08
SRMR	0.009	0.032	<0.08

GDT = Gaming Disorder Test; GADIS-A = Gaming Disorder Scale for Adolescents; CBS = Subscale of cognitive behavioral symptoms in GADIS-A; NC = Subscale of negative consequences in GADIS-A; CFI = comparative fit index; NNFI = non-normed fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual

Table 3. Item descriptions and properties

	Item description	Mean (SD)	Factor loading	Item-total correlation
GDT				
GDT_I1	I have had difficulties controlling my gaming activity	1.99 (1.01)	0.83	0.73
GDT_I2	I have given increasing priority to gaming over other life interests and daily activities	1.87 (0.98)	0.90	0.80
GDT_I3	I have continued gaming despite the occurrence of negative consequences	1.89 (1.00)	0.93	0.83
GDT_I4	I have experienced significant problems in life (e.g.,	1.75	0.87	0.76

	personal, family, social, education, occupational) due to the severity of my gaming behavior	(0.92)		
GADIS-A				
CBS subscale				
GADIS-A_I1	I often play games more frequently and longer than I planned to or agreed upon with my parents.	1.17 (1.07)	0.77	0.72
GADIS-A_I2	I often cannot stop gaming even though it would be sensible to do so or, for example, my parents have told me to stop.	1.06 (1.03)	0.88	0.83
GADIS-A_I4	I neglect daily duties, because I prefer gaming. Daily duties include, e.g., doing grocery shopping, cleaning, tidying up after myself, tidying up my room, fulfilling obligations for school/apprenticeship/job.	0.95 (0.98)	0.94	0.81
GADIS-A_I5	I continue gaming even though it causes me stress with others. This means, e.g., stress with my parents, siblings, friends, partner or teachers because of gaming.	0.90 (0.96)	0.95	0.80
NC subscale				
GADIS-A_I3	I often do not pursue interests outside the digital world because I prefer gaming. For example, I do not meet with friends/ my partner in real life, do not attend sports clubs/ societies, do not read books or make music because of gaming.	0.91 (0.97)	0.91	0.80
GADIS-A_I6	I continue gaming although it harms my performance at school (or apprenticeship/job). For example, I'm late, I do not participate in class, I neglect homework and I get worse grades because of gaming.	0.91 (0.97)	0.94	0.87
GADIS-A_I7	Due to gaming, I neglect my appearance, personal hygiene, and/ or my health. For instance, I sleep less, eat unhealthy, and/or exercise less because of gaming.	0.91 (0.96)	0.93	0.87
GADIS-A_I8	Due to gaming, I risk losing important contacts or have lost them already. This includes contacts with partners, friends, acquaintances or family.	0.88 (0.97)	0.92	0.89
GADIS-A_I9	Due to gaming, I have disadvantages at school / apprenticeship / job. For example, I got bad (final) grades, I'm unable to continue to next grade or do not graduate, I have no place for training or studying, and/ or I got a poor reference or a warning /dismissal as a result of gaming.	0.90 (0.97)	0.91	0.88

GDT = Gaming Disorder Test; GADIS-A = Gaming Disorder Scale for Adolescents;

GADIS-A_CBS = Subscale of cognitive behavioral symptoms in GADIS-A; GADIS-A_NC = Subscale of negative consequences in GADIS-A

Table 4. Measurement invariance across different groups on Gaming Disorder Test (GDT)

	Configural Model	**Loadings Constrained as Equal**	**Loadings and Thresholds Constrained as Equal**
Gender (male *vs.* female)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	15.04 (4)	8.08 (3)	6.17 (3)
CFI or Δ*CFI*	0.999	**0.000**	**-0.001**
RMSEA or *ΔRMSEA*	0.040	**-0.003**	**-0.003**
SRMR or *ΔSRMR*	0.011	**0.002**	**0.000**
Gaming hours (below 2 hours, 2 hours to 5 hours, more than 5 hours)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	23.57 (6)	17.01 (6)	12.75 (7)
CFI or Δ*CFI*	0.999	**-0.001**	**-0.001**
RMSEA or *ΔRMSEA*	0.051	**-0.005**	**-0.006**
SRMR or *ΔSRMR*	0.012	**0.016**	**0.000**
Severity in IGDS9-SF (< 32 points *vs.* ≥ 32 points)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	14.99 (4)	8.13 (3)	5.56 (3)
CFI or Δ*CFI*	0.999	**0.000**	**-0.011**
RMSEA or *ΔRMSEA*	0.040	**-0.003**	**-0.004**
SRMR or *ΔSRMR*	0.019	**0.029**	**0.000**

IGDS9-SF = Nine-item Internet Gaming Disorder Scale–Short-Form; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual. the **bold value indicates invariance**; i.e., ΔCFI > -0.01; ΔRMSEA < 0.015;

ΔSRMR < 0.03 (for factor loading) or < 0.01 (for item intercept)

Table 5. Measurement invariance across different groups on Gaming Disorder Scale for Adolescents (GADIS-A)

	Configural Model	**Loadings Constrained as Equal**	**Loadings and Thresholds Constrained as Equal**
Sex (male *vs.* female)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	211.93 (52)	**26.34 (7)**	**25.35 (7)**
CFI or Δ*CFI*	0.998	**0.000**	**-0.001**
RMSEA or *ΔRMSEA*	0.043	**-0.001**	**0.000**
SRMR or *ΔSRMR*	0.031	**0.001**	**0.000**
Gaming hours (below 2 hours, 2 hours to 5 hours, more than 5 hours)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	241.00 (78)	25.22 (14)	41.27 (16)
CFI or Δ*CFI*	0.998	**0.000**	**0.000**
RMSEA or *ΔRMSEA*	0.043	**-0.002**	**0.000**
SRMR or *ΔSRMR*	0.044	**0.002**	**0.000**
Severity in IGDS9-SF (< 32 points *vs.* ≥ 32 points)			
$X^2(df)$ or $\Delta X^2(\Delta df)$	309.64 (52)	21.81 (7)	33.46 (7)
CFI or Δ*CFI*	0.997	**-0.001**	**0.000**
RMSEA or *ΔRMSEA*	0.054	**-0.002**	**0.000**
SRMR or *ΔSRMR*	0.058	**0.010**	**0.000**

IGDS9-SF = Nine-item Internet Gaming Disorder Scale–Short-Form; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual. the **bold value indicates invariance**; i.e., ΔCFI > -0.01; ΔRMSEA < 0.015; ΔSRMR < 0.03 (for factor loading) or < 0.01 (for item intercept)

Table 6. Pearson correlations among the observed variables: *r* (*p*-value)

	1	2	3	4	5	6	7	8	9	10
1. GDT	1.00									
2. GADIS-A	.78 (<.01)	1.00								
3. GADIS-A_ CBS	.78(<. 01)	.96(<. 01)	1.00							
4. GADIS-A_ NC	.73(<. 01)	.98(<. 01)	.88(<. 01)	1.00						
5. GADIS-A_ Time criterion	.60(<. 01)	.64(<. 01)	.61(<. 01)	.63(<. 01)	1.00					
6. BSMAS	.42(<. 01)	.44(<. 01)	.43(<. 01)	.43(<. 01)	.32(<. 01)	1.00				
7. IGDS9-SF	.67(<. 01)	.66(<. 01)	.64(<. 01)	.64(<. 01)	.50(<. 01)	.65(<. 01)	1.00			
8. Time spent on smartphone	.04(.0 2)	.02(.1 8)	.06(<. 01)	-.01(.7 5)	-.03(.1 5)	.11(<. 01)	.04(.0 2)	1.00		
9. Time spent on using social media	.02(.2 3)	.03(.0 8)	.04(.0 3)	.02(.1 7)	.01(.5 7)	.13(<. 01)	.06(<. 01)	.48(<. 01)	1.00	
10. Time spent on gaming	.28(<. 01)	.24(<. 01)	.25(<. 01)	.23(<. 01)	.20(<. 01)	.12(<. 01)	.27(<. 01)	.32(<. 01)	.29(<. 01)	1.0 0

GDT = Gaming Disorder Test; GADIS-A = Gaming Disorder Scale for Adolescents; GADIS-A_CBS = Subscale of cognitive behavioral symptoms in GADIS-A; GADIS-A_NC = Subscale of negative consequences in GADIS-A; GADIS-A_Time criterion = Time criterion frequency in GADIS-A; BSMAS = Bergen Social Media Addiction Scale; IGDS9-SF = Nine-item Internet Gaming Disorder Scale–Short-Form

Table 7. Known-group validity of Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A)

	GDT				GADIS-A			
	Mean (SD)	*t* or *F*	*p*	Effect size (Cohen's *d* or η^2)	Mean (SD)	*t* or *F*	*p*	Effect size (Cohen's *d* or η^2)
Male (n=1469)	8.42 (3.61)	13.72	<0.01	*d*=0.48	10.49 (7.87)	12.71	<0.01	*d*=0.44
Female (n=1912)	6.83 (3.12)				7.15 (7.34)			
High IGD Group (n=117)	13.08 (4.24)	18.72	<0.01	*d*=1.76	20.03 (9.01)	16.89	<0.01	*d*=1.59
Low IGD Group (n=3264)	7.32 (3.23)				8.19 (7.38)			
Low gaming hours (<2 hr) (n=2093)	6.60 (2.99)	243.88[a]	<0.01	η^2=0.13	6.72 (7.08)	192.33[a]	<0.01	η^2=0.10
Medium gaming hours (2-5 hr) (n=1054)	8.75 (3.39)				11.19 (7.48)			
High gaming hours (>5 hr) (n=234)	10.19 (4.16)				13.78 (8.94)			

Note. High IGD group=participants with IGDS9-SF score ≥ 32 points (IGDS9-SF = Nine-item Internet Gaming Disorder Scale–Short-Form); low IGD group=participants with IGDS9-SF score < 32 points.

Small effect size: Cohen's *d* at 0.2 or η^2 at 0.01; Medium effect size: Cohen's *d* at 0.5 or η^2 at 0.06; Large effect size: Cohen's *d* at 0.8 or η^2 at 0.14.

[a] The results of post-hoc: high gaming hour group> medium gaming hour group> low gaming hour group

Acknowledgement

We thank the faculty members who helped distributing the online survey to the target participants. We also thank all the participants.

Funding

This research was supported in part by (received funding from) the Ministry of Science and Technology, Taiwan (MOST 110-2410-H-006-115; MOST 111-2410-H-006-100), the Higher Education Sprout Project, the Ministry of Education at the Headquarters of University Advancement at the National Cheng Kung University (NCKU), and the 2022 Southeast and South Asia and Taiwan Universities Joint Research Scheme (NCKU 35).

Conflict of interest: None.

Declaration of interest: none.

Highlights

- Gaming Disorder Test (GDT) is a new instrument assessing gaming disorder (GD).
- Gaming Disorder Scale for Adolescents (GADIS-A) is a new instrument assessing GD.
- GDT and GADIS-A both had promising psychometric properties in Chinese versions
- GDT is a one-factor structure instrument.
- GADIS-A is a two-factor structure instrument.