



Psychometric Evaluation of the Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A) Among Hong Kong University Students

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Abstract

The present study validated the Gaming Disorder Test (GDT) and the Gaming Disorder Scale for Adolescents (GADIS-A) among Hong Kong university students. Using convenience sampling, 790 participants (63% females, age = 22.5 years [± 4.4]) completed an online survey including the GDT, GADIS-A, Internet Gaming Disorder Scale-Short Form (IGDS9-SF), Depression Anxiety Stress Scale-21 (DASS-21), and Tendency to Avoid Physical Activity and Sport Scale (TAPAS). The expected factor structures of the GDT (one-factor) and GADIS-A (two-factor) were confirmed with strong factor loadings from 0.70 to 0.86. Moderate to high significant correlations between both scales and the IGDS9-SF, DASS-21, and TAPAS showed appropriate concurrent/convergent/divergent validity ($0.20 < r < 0.83$). Both scales were internally consistent ($0.88 < \alpha / \omega < 0.93$). Both scales were invariant across gender, severity of problem, and educational major. Both the GDT and GADIS-A are valid and reliable tools to assess gaming disorder among young university students in Hong Kong.

Keywords Gaming disorder · Psychometric assessment · Validation · University students · Gaming Disorder Test (GDT) · Gaming Disorder Scale for Adolescents (GADIS-A)

Introduction

The number of online gamers has grown over the past two decades, and adolescents as well as young adults comprise a considerable proportion of this population (Paulus et al., 2018). The gaming industry consistently encourages individuals to play new online games and it is estimated that the worldwide revenue of that is more than \$100 billion (US) annually (Palma-Ruiz et al., 2022). Based on available reports, there are over 200 million individuals in United States that play videogames (Stevens et al., 2020) as well as half of the European population

(Colasante et al., 2022). The prevalence rate of gaming in Asian countries (particularly those living in south-east Asia) is estimated to be higher than western countries, with some studies indicating more than 70% of adolescents and young people in these regions playing online videogames (Mohamed et al., 2023; World Health Organization, 2024; Yu & Cho, 2016; Zhang et al., 2024). A recent report from World Health Organization reported that 34% of adolescents in Europe play videogames daily (Mohamed et al., 2023; World Health Organization, 2024; Yu & Cho, 2016; Zhang et al., 2024). A pilot study among Hong Kong adolescents in 2014 reported that nearly 16% of adolescent gamers may be identified as problematic gamers. A more recent survey in this region claimed that over 30% of students spent at least five hours daily playing videogames and that this may lead to gaming addiction among this group (Leung; Wang et al., 2014).

Initially, internet gaming disorder (IGD) was included as a tentative disorder in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) (American Psychiatric Association, 2013). Several years later, gaming disorder (GD) was included in the 11th revision of the *International Classification of Diseases* (ICD-11) (World Health Organization, 2019), and is a pattern of digital gaming behavior that comprises inadequate control of gaming, prioritizing gaming over other daily activities, and continued gaming despite negative consequences. Moreover, for its diagnosis problems such as experience of significant functional impairment and clinical distress should be addressed.

According to a recent meta-analysis the global prevalence of GD is close to 3% in the total population and approximately 10% among adolescents and young adults (Gao et al., 2022). Also a systematic review showed that males are 2.5 times at higher risk of GD compared to females (Stevens et al., 2021). A study reported that 3.1% of Taiwanese adolescents experienced GD (Chiu et al., 2018), and another study estimated that one in six students at secondary schools in Hong Kong have GD (Wang et al., 2014).

Psychiatric disorders such as anxiety and depression, obsessive-compulsive disorder, substance abuse, attention-deficit with hyperactivity disorder, and other relevant addictive behaviors such as social media addiction have been reported as common comorbidities with GD (Ghali et al., 2023; Ko et al., 2021; Ohayon & Roberts, 2021). Rozgonjuk et al. (2023) found that there were significant correlations between problematic online gaming and other relevant behavioral addiction such as problematic online gambling, shopping, pornography use, and social networking (Rozgonjuk et al., 2023). Negative synergistic effects of IGD and social media addiction on each other and also on overall psychological health have also been identified (Pontes, 2017). Moreover, empirical evidence indicates a substantial correlation between GD and experiencing psychosocial problems among affected individuals that also may lead to a poor physical health (Wartberg et al., 2017). Other health concerns including visual impairment, sleep difficulties, convulsions, day-night reversal, and venous thrombosis are more common among individuals with GD than general population (Lee et al., 2017; Wichstrøm et al., 2019; Wong et al., 2020).

GD may not only affect the physical and mental health of gamers, it can have more profound negative impacts on the academic achievement, personality, and daily lifestyle of younger people. A meta-analysis showed that problematic gaming is not only correlated with common mental health problems such depression, anxiety, and obsessive compulsive disorder, but is also significantly associated with a wide range of negative health outcomes (Männikkö et al., 2020). Moreover, as shown in a representative sample of gamers, professional gamers (compared to non-professional gamers) were at higher risk of GD and its related functional impairments, and that it may negatively affect their school/work tasks (Pontes et al., 2024). A longitudinal study conducted by Nie et al. (2024) found significant negative correlations between GD and academic achievement among older-aged adolescents. Similarly, Hawi et al. (2018) reported that IGD is associated with sleep problems, younger age, and lower academic

achievement. Moreover, several studies have highlighted the role of GD in contributing to and/or being comorbid with various behavioral addictions, including addictions gambling and cigarette smoking, particularly among adolescents and young adults (Fahs et al., 2022; Hernández-Vásquez et al., 2022; Imataka et al., 2022).

To date, several instruments have been developed to assess and screen for GD. However, most of these scales were adapted in English for western countries, and their applicability and feasibility in other languages and cultures require further investigation (Wang & Cheng, 2020). Moreover, some of these instruments, such as the 10-item Internet Gaming Disorder Test (IGDT-10) (Király et al., 2017), only assess online GD rather than off-line GD. In addition, this instrument pre-dates the ICD-11. Therefore, it only assesses GD within the American Psychiatric Association (APA) framework for IGD and does not assess the ICD-11 criteria for GD (Pontes & Griffiths, 2020). Furthermore, since GD has been formally recognized in the ICD-11, there is a set of standardized diagnostic criteria that provide a framework for researchers to develop valid and reliable tools to evaluate the GD based on these criteria.

Consequently, Pontes et al. (2021) developed the Gaming Disorder Test (GDT), as a brief four-item (unidimensional) standardized measure based on ICD-11 criteria both for English and Chinese speaking individuals to address at-risk populations in western countries and Asia. The GDT was the first instrument developed to assess GD based on WHO criteria for GD with well-established psychometric properties (Pontes et al., 2021). The GDT differentiates between pathological, dangerous, and normal gaming to address symptoms, impairments, and temporal issues related to GD (Cudo et al., 2022). The GDT already has been translated and used at least in 15 languages including the German, Chinese (simplified and traditional Chinese characters), Turkish, Taiwanese, Spanish, Italian, Polish, Bangla, Malay, Spanish, Vietnamese, Arabic, Urdu, Swedish and Persian with robust psychometric evaluations that indicate its applicability for different populations and cultures (Çakıroğlu & Alnak, 2021; Cudo et al., 2022; Jahrami et

al., 2024; Lin et al., 2023; Maldonado-Murciano et al., 2021; Pontes et al., 2021; Wu et al., 2023) and is the most use scale internationally for assessing GD within the WHO framework. The GDT has also been shown to be invariant across variables such as gender, age, and job status demonstrating a high accuracy when used among individuals with different demographics (Lin et al., 2023; Siřínková et al., 2024). A review study assessing all available GD scales showed that the GDT had highest level of validation for GD criteria (i.e., criterion-related validity) as described in the WHO framework (Karhulahti et al., 2023).

In a large-scale international study, Pontes et al. (2022) assessed GD using the IGDS9-SF that was developed based on APA criteria, and the GDT that was developed based on WHO criteria. They found that prevalence of disordered gaming when assessed by GDT, was approximately two times less than the rate of GD based on the IGDS9-SF (1.96% vs. 4.97%). Moreover, the correlation between time spent for gaming and GD varied by using individual scales (34.5 hours based on IGDS9-SF vs. 40.1 hours based on GDT) (Pontes et al., 2022). In another similar study, both scales were used to assess GD psychopathological symptoms and gaming motives among German gamers. They also found minor discrepancies between prevalence rates estimated by each scale and the study suggested using GDT as a more appropriate scale to assess GD in this population (Montag et al., 2019). However, in another study that both scales were used to compare GD among professional and non-professional gamers, the authors found both scales differentiated between these two groups in terms of time spent for gaming and prevalence of GD (Maldonado-Murciano et al., 2022). Therefore, although both scales may provide comparable findings to assess GD in different populations, Pontes et al. (2021) noted that researchers should consider the emerging comparative research examining the key differences between the APA framework (for IGD) and the WHO framework (for GD).

Another GD scale that was specifically developed to assess GD based on ICD-11 criteria

among children and adolescents is the nine-item Gaming Disorder Scale for Adolescents (GADIS-A). Because there was no validated scale to assess GD in this population, the authors developed this scale originally in German (Paschke et al., 2020). The scale was then translated and adapted into Chinese, Russian and Persian (Mazaherizadeh et al., 2022; Nazari et al., 2023; Wu et al., 2023). Studies have shown that the GADIS-A (like the GDT) is a reliable and valid tool to assess the GD among younger populations. The advantage of GADIS-A compared to GDT is that the scale was specifically developed for adolescents and young populations (a population in which gaming is highly prevalent) whereas the GDT was developed for the general population (including adolescents) (Chen, Chang, et al., 2023). Therefore, the GADIS-A is narrower in scope when it comes to what populations it is best suited to assess GD whereas the GDT has a much wider application, with validation studies providing robust data for its use across the whole lifespan (Chen, Chang, et al., 2023; Ghazi et al., 2024). Another characteristic of the GADIS-A is that it was developed with the APA framework for IGD in mind because in the original validation study, the authors to cover all the DSM-5 criteria for IGD as well as the ICD-11 criteria (Paschke et al., 2020). In contrast, the GDT exclusively focuses on the WHO framework and the ICD-11 conceptualization, which is more recent than the APA framework.

Another important point for comparison concerns the brevity of the two measures. Here, the GDT has an advantage as it has only four items whereas the GADIS-A has nine items. However, both scales can be used concurrently to provide a comprehensive picture of GD in terms of diagnosis and severity of GD. Moreover, although both scales were developed similarly, the GDT appears to have more international support through many different studies summarized by a meta-analysis (Jahrami et al., 2024).

Validation studies for both GDT and GADIS-A were conducted among a large sample of 3381 emerging adults in mainland China by Chen, Chang, et al. (2023). The confirmatory factor

analysis showed a unidimensional structure for GDT and a two-factor structure for GADIS-A. Also, there was good convergent validity and appropriate concurrent validity of both scales compared to other relevant scales (Chen, Chang, et al., 2023). Moreover, the validity and reliability of the two scales among Taiwanese young people was evaluated with a sample of 608 Taiwanese university students by Wu et al. (2023). Similar to Chen, Chang, et al. (2023), the results demonstrated the same factor structures for both scales, and also indicated good internal consistency as well as measurement invariance across gender (Wu et al., 2023).

The present study

Hong Kong is a specific administrative region under governance of China with more than 7 million people mostly from different nationalities. The predominant language in the region is Cantonese (a type of Chinese dialect) that is spoken by more than 90% of the population. The traditional Chinese characters (rather than the simplified characters that are used in the mainland) comprise the formal writing style in the region. Hong Kong, with a high human development index and life expectancy, is categorized as a highly developed territory and ranks among the five highest regions in term of human development (Wikipedia, 2022). Despite the relatively close relationship of culture and language to mainland China, Hong Kong is considered as a cultural melting pot, with a mix of cultures, diverse populations, and varied living status. Therefore, the authors evaluated the psychometric properties of the GDT and GADIS-A in this territory to determine how the available Chinese translated versions of the scales performed among young adults living in Hong Kong. The present study hypothesized that the scales would (i) have acceptable convergent validity with Internet Gaming Disorder Scale-Short Form and Depression Anxiety Stress Scale-21; and divergent validity with the Tendency to Avoid Physical Activity and Sport Scale, (ii) have the same factor structures as obtained in previous studies, (iii) show acceptable range for internal consistency, and (iv) be invariant in term of variables such as gender, GD severity and study major.

Methods

Data collection and participants

The present study used a cross-sectional online survey design. Before data collection, the study protocol was approved by **BLIND FOR REVIEW**. Data were collected via an online survey hosted on *Qualtrics* between March and June in 2023. Students from 12 universities in Hong Kong were recruited using convenience sampling. More specifically, the third author of the present study and his research assistant disseminated the survey link to the emails of university students studying in Hong Kong and posted the survey link on social media platforms (e.g., *Facebook* or *Instagram*) to invite potential participants.

The first page of the online survey clearly stated the participants' right and benefits in participation (e.g., there would be no consequence for not completing the survey, the survey could be quit at any time, completing the whole survey would be recompensed with a coupon valued \$50 HK [~\$7 US]). Also, the inclusion criteria were clearly stated on the first page, which were: (i) being a local student studying in Hong Kong, (ii) being aged ≥ 18 years, and (iii) having no problem in understanding the survey questions written in traditional Chinese characters. Only the students who provided their written informed consent (electronically) after reading the information at the first page of the online survey could continue the online survey. Moreover, there were no minors needing their legally authorized representatives to provide informed consent in the present study. A total of 790 young adults residing in Hong Kong were recruited. The majority of participants were female ($n = 501$, 63.4%), with mean age of 22.5 years ($SD=4.4$), and were majoring in either medicine (23.2%), science (24.2%), or social science (52.4%).

Measures

Gaming Disorder Test (GDT). The GDT (Pontes et al., 2021) is a self-report scale that assesses

GD symptoms based on the diagnostic criteria outlined in the ICD-11 (World Health Organization, 2019). Participants are asked about their gaming behavior through four questions concerning their capacity to control gaming behavior, the priority given to gaming, the continuation of gaming, and the experience of distress or impairment because of gaming over a 12-month period. Each of the four questions is rated on a 5-point Likert scale (1=*never*; 2=*rarely*; 3=*sometimes*; 4=*often*; 5=*very often*), with higher scores indicating more severe GD symptoms. The internal consistency in the original study was found to be high ($\alpha = 0.84$) (Pontes et al., 2021).

Gaming Disorder Scale for Adolescents (GADIS-A). The nine-item GADIS-A (Paschke et al., 2020) is a self-report scale that assesses the risk of GD among adolescents, based on the diagnostic criteria outlined in the ICD-11 (World Health Organization, 2019). The GADIS-A includes the Cognitive Behavior Symptoms (CBSs) subscale (Items 1, 2, 4, and 5; e.g., “*I often play games more frequently and longer than I planned to or agreed upon with my parents*”) and the Negative Consequences (NCs) subscale (Items 3, 6, 7, 8, and 9; e.g., “*Due to gaming, I risk losing important relationships [friends, family, partner] or have lost them already*”). These are scored on a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). The items are scored based on respondents’ level of agreement with the items, with higher scores indicating a higher likelihood of experiencing GD. There are four additional questions about the frequency of experiencing impairments due to gaming (Items 10-13) with response options of “*not at all*”, “*only on single days*”, “*during longer periods*”, or “*almost daily*”. The original study reported excellent internal consistency for the GADIS-A ($\alpha = 0.91$) (Paschke et al., 2020). Recent studies have also shown that the GADIS-A demonstrates good psychometric properties for assessing GD among emerging adults (Chen, Chang, et al., 2023; Ghazi et al., 2024; Wu et al., 2023).

Internet Gaming Disorder Scale-Short Form (IGDS9-SF). The nine-item IGDS9-SF (Pontes &

Griffiths, 2015) is a self-report scale that assesses IGD based on the diagnostic criteria defined in the DSM-5 symptoms over a 12-month period (American Psychiatric Association, 2013). Participants are asked about their gaming behavior through nine items concerning their preoccupation with gaming, withdrawal symptoms when prevented from engaging in gaming, the urge to participate in gaming, inability to quit gaming, persisting in gaming even when facing difficulties, lying about the amount of time spent on gaming, using gaming to relieve negative moods, and having been jeopardized due to gaming. All nine items are scored using a 5-point Likert scale from 1 (*never*) to 5 (*very often*), with higher scores suggesting more severe symptoms. The internal consistency of the original study was found to be good (Pontes & Griffiths, 2015).

Depression Anxiety Stress Scale-21 (DASS-21). The DASS-21 (Lovibond et al., 1995) is a self-report scale that assesses the level of psychological distress. It includes seven items for three types of psychological distress (i.e., depression, anxiety, and stress). All 21 items (e.g., “*I felt that I was using a lot of nervous energy*”) are rated on a 4-point Likert scale by asking how much the statement applied to the respondent over the past week, ranging from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*), with higher scores indicating greater psychological distress. Prior research has demonstrated satisfactory internal consistency for the DASS-21 (Cao et al., 2023; Chen, Chen, et al., 2023).

Tendency to Avoid Physical Activity and Sport Scale (TAPAS). The 10-item TAPAS (Bevan et al., 2022) is a self-report scale that assesses the avoidance of physical activity and sports related to weight-associated self-stigma. Half of the items assess physical activity (e.g., “*I avoid physical activity because I might get teased about my weight*”) and the other half assess sporting activity (e.g., “*I find myself avoiding participating in sport because of my weight*”). Each item is scored on a five-point scale from 1 (*strongly disagree*) to 5 (*strongly agree*), with higher scores indicating a stronger inclination to avoid physical activity or sport. The original

TAPAS demonstrated excellent internal consistency ($\alpha = 0.95$) (Bevan et al., 2022).

Demographic variables. Data regarding the following demographic variables were collected: age (in years), sex (male or female), school study major (medicine, science, or social science), internet use per day (reported in hours), and physical activity per day (reported in hours). All the items from all the scales are listed in Supplementary material A.

Permission for using the measures in the present study

The present authors obtained permission from the developers of GDT, GADIS-A, and TAPAS to use them. The DASS-21 is in the public domain and did not require permission from the developers to use the scale.

Data analysis

The participants' demographics and scores on the measures were analyzed and summarized using the descriptive statistics. Skewness and kurtosis were used to examine the data normality. An absolute skewness value < 3 and kurtosis value < 10 were considered as being within the acceptable range (Kline, 2023). Then, confirmatory factor analysis (CFA) and two types of internal consistency (Cronbach's α and McDonald's ω) were used to examine the item-level (i.e., factor loadings in the CFA [> 0.4 indicates satisfactory] and item-rest correlations in internal consistency [> 0.4 indicates satisfactory]) (Huang et al., 2024; Lin et al., 2023) and scale-level (i.e., fit indices in the CFA [please see the next paragraph for details] and the overall internal consistency values [> 0.7 indicates acceptable for both Cronbach's α and McDonald's ω]) (Wu et al., 2023; Yang et al., 2023) for both GDT and GADIS-A.

CFA was performed using the diagonally weight least squares (DWLS) estimator to evaluate the ordinal scale in both the GDT and GADIS-A. For the GDT, a one-factor structure was evaluated (i.e., to see if all four items loaded on the same concept of GD). For the GADIS-A, a two-factor structure was evaluated (i.e., to see if Items 1, 2, 4, and 5 loaded on the concept of CBSs; and Items 3, 6, 7, 8, and 9 loaded on the concept of NCs). Model fit was then assessed

using the following fit indices: comparative fit index (CFI) > 0.9 , Tucker-Lewis index (TLI) > 0.9 , root mean square error of approximation (RMSEA) < 0.08 , and standardized root mean square residual (SRMR) < 0.08 (Leung et al., 2020; Nadhiroh et al., 2022).

After confirming the factor structures for both the GDT, and GADIS-A, multigroup CFA was used to examine if the confirmed factor structures were invariant across gender (male vs. female), severity of IGD (IGDS9-SF score < 32 vs. IGDS9-SF score ≥ 32), and school degree major (medicine, science, and social science). Two sets of three nested models were constructed in the multigroup CFA: one set of nested models for GDT to examine its measurement invariance; another set for GADIS-A.

The three nested models included (i) a configural model, (ii) a metric invariance model, and (iii) a scalar invariance model (Huang et al., 2024; Leung et al., 2020). The configural model examines if a proposed factor structure (i.e., one-factor structure for the GDT and two-factor structure for the GADIS-A) fit well in all subgroups (i.e., male and female subgroups for gender; at-risk IGD and non-at-risk IGD subgroups for IGD severity; and medicine, science, and social Science subgroups for school degree major). The metric invariance model constrains the factor loadings being equal across subgroups in the configural model to see if fit indices remain good. The scalar invariance model constrains factor loadings and item thresholds being equal across subgroups in the configural model to see if fit indices remain good (Huang et al., 2024; Leung et al., 2020).

To determine whether the fit remained adequate across nested models, the following guidelines from Chen (2007) were adopted: for metric invariance (i.e., factor loadings), a decrease in CFI of no more than 0.01 ($\Delta\text{CFI} \leq 0.01$), an increase in RMSEA of no more than 0.015 ($\Delta\text{RMSEA} \leq 0.015$), and an increase in SRMR of no more than 0.03 ($\Delta\text{SRMR} \leq 0.03$) were considered acceptable. For scalar invariance (i.e., item thresholds), the same CFI and RMSEA criteria were used, but a stricter cutoff of $\Delta\text{SRMR} \leq 0.01$ was employed. If these

criteria were not met, item parameters were relaxed one at a time to assess partial invariance, as recommended (Finch, 2014; Wang et al., 2018).

Finally, based on the results of the normality testing, Spearman correlations (for non-normal distributed variables) or Pearson correlations (for normal distributed variables) were chosen to examine the correlations between the study variables. Based on Cohen's (2013) suggestion, correlation effect at 0.1 is small, at 0.3 is moderate, and at 0.5 is large. All the analyses were performed using the JASP software (*JASP*, 2024; Allaire, 2020), except for the CFA and multigroup CFA, which used the *lavaan* package in R software (Rosseel, 2012).

Results

Participant characteristics, measure scores, and normality testing for studied measures

Table 1 reports the baseline characteristics and results of all study variables among the 790 participants. There were no missing data. Their mean GD scale scores were 8.22 for GDT (SD=3.44), 8.73 for GADIS-A total score (SD=7.48), 4.77 for GADIS-A CBSs subscale score (SD=3.79), and 3.97 for GADIS-A NCs subscale score (SD=4.06). Additional scores for the other measures are reported in Table 1. In addition, they spent 2.87 hours daily using social media (SD = 1.78), 5.30 hours daily using their smartphone (SD = 2.71), 1.22 hours daily online learning (SD = 1.48), and 2.21 hours daily engaged in outdoor physical activity (SD = 2.34).

The results of the normality testing showed that all the items and subscales in the GDT, GADIS-A, and DASS-21 had skewness values ranging between 0.353 and 1.398, and the kurtosis values ranging between -1.141 and 1.335 (Supplementary Table 1). These results suggested that all the items and subscales were distributed normally.

(Insert Table 1 here)

Item properties and factor structure for GDT and GADIS-A

Item properties of the GDT and GADIS-A are presented in Table 2. All GDT items had strong factor loadings in standardized estimates (loadings = 0.81, 0.82, 0.86, and 0.70 for GDT Items 1 to 4, respectively). Similarly, all GADIS-A items had strong factor loadings in standardized estimates: for CBSs, loadings = 0.74, 0.81, 0.84, and 0.82 for GADIS-A Items 1, 2, 4, and 5, respectively; = 0.79, 0.85, 0.78, 0.76, and 0.76 for Items 3, 6, 7, 8, and 9, respectively. Both GDT and GADIS-A had satisfactory item-rest correlations (values = 0.65 to 0.79 for GDT; 0.70 to 0.80 for GADIS-A). Based on the satisfactory item properties, both GDT and GADIS-A showed good scale properties. More specifically, internal consistency was good for GDT, the two subscales of GADIS-A (i.e., CBSs and NCs), and the entire GADIS-A irrespective of using α or ω coefficients (Table 3). The CFA fit indices supported the one-factor structure for the GDT (CFI = 1.000, TLI = 0.999, RMSEA = 0.017, and SRMR = 0.021) and the two-factor structure for the GADIS-A (CFI = 0.993, TLI = 0.990, RMSEA = 0.051, and SRMR = 0.054), indicating an excellent fit to the data.

(Insert Tables 2 and 3 here)

Measurement invariance findings for GDT and GADIS-A

The one-factor structure of the GDT was then found to be invariant across the three study majors of the participants (i.e., medicine, science, and social science) at both metric and scalar level (all Δ CFI and Δ RMSEA = 0.000; Δ SRMR = 0.006 and 0.004). The one-factor structure of the GDT was also invariant across gender and severity of IGD (based on cutoff score of the IGDS9-SF) at metric level (all Δ CFI and Δ RMSEA = 0.000; Δ SRMR = 0.006 and 0.001). However, one GDT item (i.e., Item 4 [*Significant problems due to gaming*]) needed to be relaxed to achieve scalar invariance across gender and IGD severity for the GDT (Table 4). Following the measurement invariance models, the female group compared with male group had a relatively low GDT latent mean (-0.315 vs. 0); the less severe IGD group compared with more severe IGD group had a substantial low GDT latent mean (-1.790 vs. 0); the Medicine

major and Social Science major groups compared with Science major group had a slightly low GDT latent mean (-0.102, -0.101, and 0).

(Insert Figure 1 and Table 4 here)

The two-factor structure of the GADIS-A was also found to be invariant across study major at both metric and scalar level ($\Delta\text{CFI} = 0.000$ and 0.001 ; $\Delta\text{RMSEA} = -0.001$ and -0.009 ; $\Delta\text{SRMR} = 0.004$ and 0.001). The GADIS-A structure was also invariant across gender ($\Delta\text{CFI} = 0.000$ and 0.000 ; $\Delta\text{RMSEA} = 0.001$ and -0.005 ; $\Delta\text{SRMR} = 0.003$ and 0.000) and IGD severity ($\Delta\text{CFI} = -0.001$ and -0.001 ; $\Delta\text{RMSEA} = 0.001$ and -0.002 ; $\Delta\text{SRMR} = 0.001$ and 0.00) at both metric and scalar level without relaxing any item (Table 4). Following the measurement invariance models, the female group compared with male group had a relatively low GADIS-A latent mean (-0.339 [CBSs] and -0.302 [NCs] vs. 0); the less severe IGD group compared with more severe IGD group had a substantial low GADIS-A latent mean (-1.952 [CBSs] and [NCs] vs. 0); the Medicine major and Social Science major groups compared with Science major group had a slightly low GADIS-A latent mean (-0.159 and -0.117 [CBSs]; -0.079 and -0.095 [NCs] with 0).

Concurrent validity, convergent validity, and divergent validity for GDT and GADIS-A

Therefore, Pearson correlations were chosen to examine the concurrent/convergent/divergent validity. All the correlations between study variables were statistically significant (Table 5). In brief, the GDT total score was highly correlated with all GADIS-A scores (including subscale scores and total score; $r = 0.72$ to 0.80) and IGDS9-SF score ($r = 0.80$). All GADIS-A scores were highly correlated with IGDS9-SF score ($r = 0.79$ to 0.83). Correlations of moderate to large effect sizes were found in the associations between DASS-21 score and GDT and GADIS-A scores ($r = 0.39$ to 0.44); correlations of small to moderate effect sizes were found in the associations between TAPAS score and GDT and GADIS-A scores ($r = 0.20$ to 0.24).

(Insert Table 5 here)

Discussion

The present study evaluated the psychometric properties of two common scales that assess GD using ICD-11 criteria (i.e., GDT and GADIS-A). The study used multiple methods to provide a comprehensive validation of these scales and to find how reliable and valid they were in screening GD among young university students in Hong Kong. Findings were promising and indicated both scales had acceptable concurrent and convergent validity and had factor structures that were that as those found in the original validation studies (i.e., one factor for GDT, and two factors for GADIS-A).

Moreover, both item-total correlations and internal consistency (α and ω) coefficients indicated robust reliabilities of the scales. Both scales demonstrated measurement invariance, indicating the applicability of the scales to assess GD accurately among individuals using different characteristics (i.e., gender, education major, and degree of gaming severity). Therefore, all study hypotheses were supported and the scales appear to be appropriate for use among young individuals in Hong Kong.

The factor loadings in both scales were comparable with previous studies and indicated that the theoretical basis on which they were developed appears to be robust. When developing the GDT, Pontes et al. (2021) presumed that the scale would have a unidimensional factor structure because the four items included there all were related to key indicators and clinical symptoms defined to identify GD based on the ICD-11 criteria. They also wanted to develop an instrument that not only assessed GD (as defined by the ICD-11) but also to be concise with as few items as possible (Pontes et al., 2021). The unidimensional structure of the scale has also been reported in the Polish, Spanish, Taiwanese, Persian, Czech, Malay, and Chinese versions of the scale (Chen, Chang, et al., 2023; Cudo et al., 2022; Ghazi et al., 2024; Lin et

al., 2023; Maldonado-Murciano et al., 2021; Siřínková et al., 2024; Wu et al., 2023). Therefore, all psychometric assessments of the GDT in the literature have reported the scale's unidimensional structure.

In developing the GADIS-A, Paschke et al. (2020) posited that cognitive behavioral symptoms and negative consequences of GD should both be included in their scale, so they presumed that a two-factor solution would best represent the factorial structure. They first used exploratory factor analysis to identify the initial structure of the scale. This was followed by confirmatory factor analysis which confirmed the scale's two-factor solution (Paschke et al., 2020). As the literature shows, the factor structure of the GADIS-A has also been examined through Russian, Farsi, Turkish and Chinese versions of the scale (Çakıroğlu & Alnak, 2021; Chen, Chang, et al., 2023; Mazaherizadeh et al., 2022; Nazari et al., 2022). All of these have similarly reported that the two-factor solution is appropriate to describe the scale's structure.

For convergent validity, both original validation studies in developing the GDT and GADIS-A used the IGDS9-SF. The IGDS9-SF was also used in the present study and significant correlations were found between the total scores of these three scales. However, Pontes et al. (2021) noted that the IGDS9-SF was used in their study to test for concurrent validity rather than convergent validity. Although the GDT and IGDS9-SF were developed to assess similar concepts (i.e., IGD and GD), they do not assess exactly the same disorder. Therefore, the present study preferred to say the findings are indicative of convergent validity rather than concurrent validity. However, in the present study included two instruments that were developed based on the ICD-11 criteria (i.e., the GDT and GADIS-A) among individuals with relatively different age ranges. Therefore, this may be considered as a method of assessing concurrent validity, and since the correlations between these two scales were stronger than other scales used, this shows they have an acceptable level of such validity. Concurrent use of these scales to examine their associations has also been reported in the previous studies (Chen,

Chang, et al., 2023; Ghazi et al., 2024; Wu et al., 2023).

As anticipated, both measures chosen in the present study to assess convergent/divergent validity (DASS-21 and TAPAS) showed mild to moderate correlations with the two GD scales. The correlations between DASS-21 scores and the two GD scales indicated (as proposed in the literature) that there were significant (although not very strong) relationships between poor mental health status and those with higher GD scores. Also, as hypothesized, individuals who had higher GD scores, were less likely to be engaged in physical activity. Examples of scales that have been used to evaluate convergent validity in previous studies included: DASS-21, Motives for Online Gaming Questionnaire, Mini International Personality Item Pool-Five-Factor Model, Bergen Social Media Addiction Scale, Insomnia Severity Index, and Emotional Regulation Scale (Chen, Chang, et al., 2023; Cudo et al., 2022; Mazaherizadeh et al., 2022; Wu et al., 2023). This shows that these scales (i.e., GDT and GADIS-A) and the construct that they assess (i.e., GD) may be differentiated easily from other related constructs, confirming independence of the scales to assess the unique concept of GD and having robust constructs.

It should also be noted that both scales were generally invariant across variables comprising gender, educational study major, and severity of IGD. The present study used two methods to assess invariance feature of these scales (i.e., metric and scalar). The GADIS-A was invariant at both levels. However, the GDT was invariant at the metric level (i.e., the whole scale), whereas in scalar level, one item was needed to be relaxed to reach whole scale invariance. To better understand this, the difference between these two levels of invariance needs explaining. Overall, metric invariance indicates that all categories of participants' characteristics (gender, study major, and IGD severity in the present study), interpret these scales similarly, and so similar measurements would be expected irrespective of these characteristics. However, scalar invariance examines if the latent variable is different between the categories. Therefore, the scalar invariance has a more subjective assessment of invariance

than metric invariance, and where there is less objectivity of any measures, such invariance may be different (Putnick & Bornstein, 2016). In other words, although the GDT was shown to be invariant at both metric and scalar levels in previous studies (Chen, Chang, et al., 2023; Wu et al., 2023), the latent variable in the GDT may somehow be different in the present study conducted among young university students in Hong Kong. In addition, the “*significant problems due to gaming*” (Item 4) may also be understood differently in the present study sample than those surveyed in previous studies. Moreover, because Item 4 was non-invariant at scalar level across both gender and GD severity, this may indicate different interpretation of the subgroups (i.e., females vs. males, and less severe GD vs. more severe GD) regarding the significant problems in their life resulting from problematic gaming behavior. Therefore, gender and GD severity should be considered as potential external factors that may affect accurate measurement of gaming disorder among individuals who have different situations in term of these variables. This needs further investigation through cross-sectional and longitudinal studies.

Overall, when comparing the findings of the present study with two previous studies that concurrently validated both the GDT and GADIS-A among samples from China and Taiwan individuals, the findings were similar (despite the slightly different sample characteristics). The findings of all these studies indicated that the two scales are appropriate for use among adolescent and emerging adults from Eastern Asian countries. However, the present study had two perspectives that differentiated the present findings from those of previous studies. The first was the use a new psychometric scale (i.e., the TAPAS) which helped understand the association between avoidance of physical activity and the severity of GD. The results indicated positive associations between these two variables. The second was that the study showed that a scale that had specifically designed for adolescents (i.e., the GADIS-A) could also feasibly be used among university students, something that has also been reported on one of the

previous studies (Wu et al., 2023).

The advantages of the present study compared to other related studies are: (i) it contributes to a better understanding on assessing GD based on different criteria (APA vs. WHO frameworks) and showed that the new criteria suggested by WHO may provide a strong basis to assess GD, perhaps with a more comprehensive approach to evaluate both online and offline games; (ii) the applicability of a newly developed instrument (i.e., GADIS-A) for an emerging adult population, and even for a general population (given the comparable findings with GDT); and (iii) the feasibility of using both scales (GDT and GADIS-A) among the Hong Kong population that comprises individuals from different cultures indicating the appropriateness of both scales for heterogeneous populations.

Generally, the present study had some strengths such as recruiting a sufficient sample size, using an online survey platform to increase accessibility to potential respondents, applying multiple measures to assess different aspects of validity, and using advanced statistical methods to provide a comprehensive validation process. However, there were some limitations that should be noted when interpreting the findings. First, a convenience sampling method was used that may decrease the generalizability (external validity) of the present findings for all young students in Hong Kong. Second, prior research has shown that males may have higher risk of GD than females (Stevens et al., 2021), and the present sample contained more females (i.e., > 60%). This unbalanced gender distribution may be due to the selection bias (i.e., females as compared to males are more willing to respond to online surveys). This may also affect external validity of present findings and jeopardize the generalizability for both genders. Third, the GADIS-A was originally developed for adolescents, but the present study only recruited young adults rather than adolescents. However, prior research has shown that the GADIS-A is also feasible for young adults, and therefore this limitation may not be serious (Wu et al., 2023). However, the lack of adolescent participants made it impossible for the present study to

examine measurement invariance across different age groups/developmental stages. It is important for researchers and healthcare providers to know if the two scales are equally suitable for different developmental stages. In order to diminish such a limitation, future validation studies should recruit participants from both adolescents and young adults and conduct subgroup analyses to better understand the appropriateness of these scales in such groups. However, one thing that should be addressed when using the GADIS-A for emerging adults or university students – that was not done in the present study – is that some items may need minor modifications because the items were developed for adolescents (e.g., *“I often play games more frequently and longer than I planned to or agreed upon with my parents”*). The characteristics or types of behaviors among university students may be different to adolescents, and this may affect the appropriateness of the scale when assessing different age groups. Finally, the data were all self-report, and there were no clinical or objective measures in addressing GD. Therefore, the findings may be different from those if clinical assessments had been made. The assessment of GD symptoms by expert clinicians in the future studies would resolve this limitation. Also, using longitudinal (rather than cross-sectional) designs to evaluate the variables over time may increase the validity of the findings.

Conclusion

Findings from the present study indicated that both the GDT and GADIS-A are valid and reliable instruments to assess GD among young university students in Hong Kong. These scales may concurrently and interchangeably be used to diagnose young gamers who are at risk of problematic gaming. However, using both scales concurrently may provide a more comprehensive perspective on both prevalence and severity of the GD particularly among youth. Although the scales were invariant across gender, IGD severity, and study major, the similarity of latent variables in these scales especially for GDT among different categories of

individual particularly among males vs. females and those with higher severity of GD compared to those with less GD severity needs further investigation. Applying the scales in other cultures and communities and among individuals with different demographic variables may also help to better understand their applicability and properties of GD in these various populations. Moreover, using these scales among young people from different age ranges may provide further information on likely differences of GD and its associations with other relevant variables based on the developmental stages.

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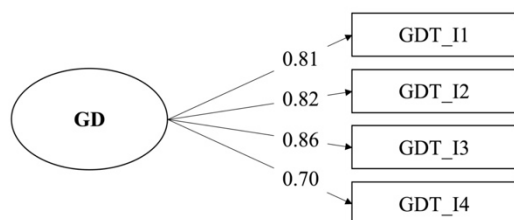
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Figures

1a



1b

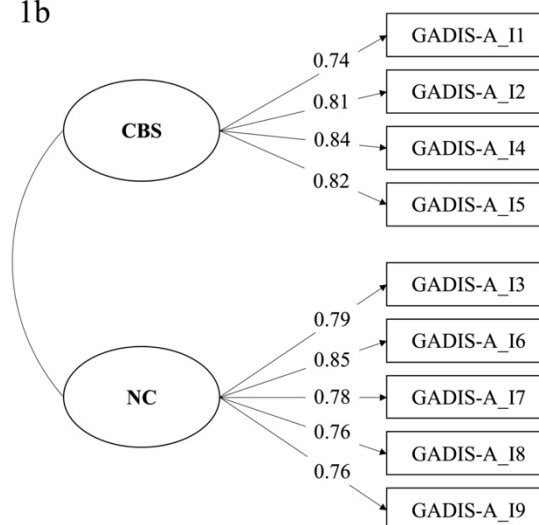


Figure 1. Illustrations of confirmatory factor analysis results for Gaming Disorder Test (1a)

and Gaming Disorder Scale for Adolescents (GADIS-A).

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

CBSs = cognitive behavioral symptoms; NCs = negative consequences

Tables

Table 1. Characteristics of the study sample (N=790)

Variable	Mean (SD) or n (%)
Age (in years)	22.5 (4.4)
Sex (female)	501 (63.4)
Major	
Medicine	183 (23.2)
Science	193 (24.2)
Social Science	414 (52.4)
Internet use (hours per day)	
Time spent using social media	2.87 (1.78)
Time spent using smartphone	5.30 (2.71)
Time spent on online learning	1.22 (1.48)
Outdoor activity (hours per day)	2.21 (2.34)
Scales of (internet) gaming disorder	
GDT	8.22 (3.44)
GADIS-A (T)	8.73 (7.48)
GADIS-A (CBSs)	4.77 (3.79)
GADIS-A (NCs)	3.97 (4.06)

IGDS9-SF	16.6 (6.99)
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Scale for psychological distress

DASS-21	32.29 (24.12)
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Scale for physical activity

TAPAS	26.12 (9.17)
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GDT = Gaming Disorder Test; GADIS-A (T) = Gaming Disorder Scale for Adolescents (Total score); GADIS-A (CBSs) = Gaming Disorder Scale for Adolescents (cognitive behavioral symptoms subscale score); GADIS-A (NCs) = Gaming Disorder Scale for Adolescents (negative consequences subscale score); IGDS9-SF = Nine-item Internet Gaming Disorder Scale-Short Form; DASS-21 = Depression Anxiety Stress Scale-21; TAPAS = Tendency to Avoid Physical Activity and Sport Scale

Table 2. Item contents and item properties of the Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A) (N=790)

	Item content	Mean (SD)	Factor loading	Item-rest correlation
GDT				
GDT_I1	Difficulty in controlling gaming activity	2.30 (1.01)	0.81	0.74
GDT_I2	Increased priority to gaming over other activities	2.06 (0.99)	0.82	0.75
GDT_I3	Continued gaming despite negative consequences	2.11 (1.10)	0.86	0.79
GDT_I4	Significant problems due to gaming	1.75 (0.93)	0.70	0.65
GADIS-A				
CBSs subscale				
GADS-A_I1	More frequent on gaming	1.57 (1.25)	0.74	0.70

GADS-A_I2	Unable to stop gaming	1.30 (1.14)	0.81	0.75
GADS-A_I4	Neglect daily duties due to gaming	1.12 (1.13)	0.84	0.79
GADS-A_I5	Continue gaming despite causing stress	0.78 (0.91)	0.82	0.78
NCs subscale				
GADS-A_I3	No other interests except for gaming	0.83 (0.96)	0.79	0.74
GADS-A_I6	Continue gaming although harming school/apprenticeship/job performance	0.84 (1.00)	0.85	0.80
GADS-A_I7	Neglect health due to gaming	0.94 (1.08)	0.78	0.74
GADS-A_I8	Lose important contacts due to gaming	0.64 (0.85)	0.76	0.73
GADS-A_I9	Have disadvantages at school/apprenticeship/job due to gaming.	0.71 (0.98)	0.76	0.71

CBSs = cognitive behavioral symptoms; NCs = negative consequences

Table 3. Confirmatory factor analysis and internal consistency of the Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A) (N=790)

	GDT	GADIS-A
McDonald's ω	0.88	0.93 [entire GADIS-A]; 0.88 [CBSs]; 0.89 [NCs]
Cronbach's α	0.88	0.93 [entire GADIS-A]; 0.87 [CBSs]; 0.89 [NCs]
χ^2 (df)	2.452 (2)	79.779 (26)
CFI	1.000	0.993
TLI	0.999	0.990
RMSEA	0.017	0.051
SRMR	0.021	0.054

CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

CBSs = cognitive behavioral symptoms; NCs = negative consequences.

Table 4. Measurement invariance of the Gaming Disorder Test (GDT) and Gaming Disorder Scale for Adolescents (GADIS-A) across gender (male vs. female), across severity of gaming disorder (IGDS9-SF score <32 vs. IGDS9-SF score ≥ 32) and across major (Medicine, Science, and Social Science) (N=790).

Across gender	GDT				GADIS-A		
	M0	M1vs.M0	M2 vs. M1	M2P vs. M1	M0	M1vs.M0	M2 vs.M1
$\chi^2(df)/p$ -value	2.773 (4)/ 0.596	--	--	--	85.487(52)/ 0.002	--	--
$\Delta \chi^2(\Delta df)/p$ -value	--	2.046 (3)/ 0.563	11.822 (3)/ 0.008	0.31(2)/ 0.856	--	13.125 (7)/ 0.0069	1.365 (7)/ 0.987
CFI	1.000	--	--	--	0.995	--	--
Δ CFI	--	0.000	-0.005	0.000	--	0.000	0.000
RMSEA	0.000	--	--	--	0.040	--	--

Δ RMSEA	--	0.000	0.041	0.000	--	0.001	-0.005
SRMR	0.018	--	--	--	0.051	--	--
Δ SRMR	--	0.006	0.004	0.001	--	0.003	0.000

Across IGDS9-SF score	M0	M1vs.M0	M2 vs. M1	M2P vs. M1	M0	M1vs.M0	M2 vs.M1
$\chi^2(\text{df})/p\text{-value}$	3.818 (4)/	--	--	--	119.197 (52)/	--	--
	0.431				0.000		
$\Delta \chi^2(\Delta\text{df}) / p\text{-value}$	--	1.206 (3)/	11.59 (3)/	0.487 (2)/	--	18.664 (7)/	9.049 (7)/
		0.752	0.009	0.784		0.009	0.249
CFI	1.000	--	--	--	0.990	--	--
Δ CFI	--	0.000	-0.005	0.000	--	-0.001	-0.001
RMSEA	0.000	--	--	--	0.057	--	--

Δ RMSEA	--	0.000	0.041	0.000	--	0.001	-0.002
SRMR	0.020	--	--	--	0.057	--	--
Δ SRMR	--	0.001	0.007	0.000	--	0.001	0.000
Across Major	M0	M1vs.M0	M2vs.M1	M0	M1vs.M0	M2 vs.M1	
χ^2 (df)/ <i>p</i> -value	2.743 (6)/	--	--	94.032 (78)/	--	--	
	0.84			0.104			
$\Delta \chi^2$ (Δ df)/ <i>p</i> -value	--	2.166 (6)/	2.238 (6)/	--	15.704 (14)/	5.212 (14)/	
		0.904	0.897		0.332	0.983	
CFI	1.000	--	--	0.998	--	--	
Δ CFI	--	0.000	0.000	--	0.000	0.001	
RMSEA	0.000	--	--	0.028	--	--	

Δ RMSEA	--	0.000	0.000	--	-0.001	-0.009
SRMR	0.018	--	--	0.053	--	--
Δ SRMR	--	0.006	0.004	--	0.004	0.001

M0 = configural model; M1 = model with loadings constrained equal; M2 = model with loadings and thresholds constrained equal; M2P = model with loadings, thresholds constrained equal and GDT item 4 was relaxed.

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

Bold values indicate invariance: Δ CFI > -0.01; Δ RMSEA < 0.015; Δ SRMR < 0.03 (for factor loading) or < 0.01 (for item threshold).

Latent GDT means = 0 (male), -0.315 (female); 0 (IGDS9-SF score < 32), -1.790 (IGDS9-SF score $\geq$ 32); and -0.102 (Medicine), 0 (Science), and -0.101 (Social Science).

Latent GADIS-A means for cognitive behavioral symptoms subscale score = 0 (male), -0.339 (female); 0 (IGDS9-SF score < 32), -1.952 (IGDS9-SF score $\geq$ 32); and -0.159 (Medicine), 0 (Science), and -0.117 (Social Science).

Latent GADIS-A means for negative consequences subscale score = 0 (male), -0.302 (female); 0 (IGDS9-SF score < 32), -1.839 (IGDS9-SF score $\geq$ 32); and -0.079 (Medicine), 0 (Science), and -0.095 (Social Science).

Table 5. Pearson correlations among the observed variables (N=790)

	<i>r</i> (<i>p</i> -value)						
	1	2	3	4	5	6	7
1. GDT total score	1.00						
2. GADIS-A CBSs score	0.80 (<.001)	1.00					
3. GADIS-A NCs score	0.72 (<.001)	0.81 (<.001)	1.00				
4. GADIS-A total score	0.80 (<.001)	0.95 (<.001)	0.95 (<.001)	1.00			
5. IGDS9-SF total score	0.80 (<.001)	0.79 (<.001)	0.79 (<.001)	0.83 (<.001)	1.00		
6. DASS-21 total score	0.44 (<.001)	0.39 (<.001)	0.43 (<.001)	0.43 (<.001)	0.51 (<.001)	1.00	
7. TAPAS total score	0.23 (<.001)	0.20 (<.001)	0.24 (<.001)	0.23 (<.001)	0.23 (<.001)	0.31 (<.001)	1.00

GDT = Gaming Disorder Test; GADIS-A = Gaming Disorder Scale for Adolescents; CBSs = cognitive behavioral symptoms; NCs = negative consequences; IGDS9-SF = Nine-item Internet Gaming Disorder Scale-Short-Form; DASS-21 = Depression Anxiety Stress Scale-21; TAPAS = Tendency to Avoid Physical Activity and Sport Scale