AKADÉMIAI KIADÓ

Journal of Behavioral Addictions

DOI:
10.1556/2006.2024.00066

FULL-LENGTH REPORT

A case-control study for psychiatric comorbidity and associative factors of gaming disorder and hazardous gaming based on ICD-11 criteria: Cognitive control, emotion regulation, and reinforcement sensitivity

JU-YU YEN[1,2], ORSOLYA KIRÁLY[3,4], MARK D. GRIFFITHS[5], ZSOLT DEMETROVICS[3,4,6] and CHIH-HUNG KO[1,7*]

[1] Department of Psychiatry, Kaohsiung Medical University Hospital, Kaohsiung Medical University, Kaohsiung City, Taiwan

[2] Department of Psychiatry, Kaohsiung Medical University Gangshan Hospital, Kaohsiung City, Taiwan

[3] Institute of Psychology, ELTE Eötvös Loránd University, Budapest, Hungary

[4] Centre of Excellence in Responsible Gaming, University of Gibraltar, Gibraltar, Gibraltar

[5] International Gaming Research Unit, Psychology Department, Nottingham Trent University, Nottingham, United Kingdom

[6] College of Education, Psychology and Social Work, Flinders University, Adelaide, Australia

[7] Department of Psychiatry, Kaohsiung Municipal Siaogang Hospital, Kaohsiung Medical University, Kaohsiung City, Taiwan

Received: April 3, 2024 • Revised manuscript received: September 6, 2024 • Accepted: October 27, 2024

ABSTRACT

Background and aims: The authors of the present study wanted to know whether the previously reported psychiatric comorbidities of internet gaming disorder (IGD) based on DSM-5 criteria were also more prevalent among gaming disorder (GD) or hazardous gaming (HG) based on ICD-11 criteria. Therefore, the present case-control study evaluated the psychiatric comorbidities and associative factors of GD and HG based on ICD-11 criteria. *Methods:* A sample of 60 individuals with GD, 45 with HG, and 120 controls were assessed with an ICD-11 criteria-based diagnostic interview along with attention deficit hyperactivity disorder (ADHD), generalized anxiety disorder (GAD), depressive disorder, and social anxiety disorder (SAD). Participants also completed Conners' Continuous Performance Test (CCPT), Dickman's Impulsivity Inventory, the Emotion Regulation Questionnaire, and the Behavior Inhibition System and Behavior Approach System Scales. *Results:* GD was associated with ADHD, depressive disorder, and GAD. ADHD was the most associative comorbidity of HG. Depressive disorder was associated with GD relative to HG. Moreover, individuals with lower reappraisal, higher aversion sensitivity, and impulsivity were more likely to be diagnosed with GD. Those with higher fun-seeking were more likely to be diagnosed with HG. *Conclusion:* In the present study, ADHD was the psychiatric comorbidity most significantly associated with GD, followed by depressive disorder and GAD, as previously reported for IGD. ADHD was also associated with HG. Depressive disorder was more associated with GD compared to HG. Intervention for HG and GD should be tailored by the consideration of the clients' psychiatric comorbidity as well as their reappraisal skills, impulsivity, aversion sensitivity, and fun-seeking.

*Corresponding author.
E-mail: chihhungko@gmail.com

KEYWORDS

gaming disorder, hazardous gaming, ICD-11 diagnosis, comorbidity, ADHD

INTRODUCTION

The fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association [APA], 2013) included internet gaming disorder (IGD) as a tentative disorder because of its negative consequences on mental health. The 11th revision of the *International Classification of Diseases* (ICD-11; World Health Organization [WHO], 2019) formally included gaming disorder (GD) with official diagnostic criteria to identify individuals needing intervention (Poznyak, Reed, & Medina-Mora, 2018). Cognitive control function, emotion regulation ability, and reward sensitivity have been suggested as three essential domains that contribute to the development of GD (Dong & Potenza, 2014; Kuss, Pontes, & Griffiths, 2018; Yen et al., 2022b). Moreover, knowledge concerning psychiatric comorbidities—such as attention deficit hyperactivity disorder (ADHD), depressive disorder, and anxiety disorder—are crucial in evaluating and treating GD (Ko et al., 2021, 2023). However, the association between psychiatric comorbidity and the three aforementioned domains and GD and hazardous gaming based on ICD-11 has not been evaluated.

The ICD-11 criteria of gaming disorder and hazardous gaming

There are nine DSM-5 criteria for internet gaming disorder (IGD) and individuals who exhibit five or more symptoms or functional impairment over 12 months are diagnosed as having IGD (APA, 2013). The ICD-11 criteria define gaming disorder (GD) as a dysfunctional pattern of gaming behavior characterized by impaired control, a greater emphasis placed on gaming over other interests and daily activities, continued gaming despite negative consequences, and evidence of functional impairment (WHO, 2019). As all criteria should be fulfilled in ICD-11, GD criteria usually have a higher diagnostic intensity threshold than IGD criteria in the DSM-5 (Yen, Chou, Liao, & Ko, 2023). Although there are differences between the DSM-5 IGD criteria and the ICD-11 GD criteria, two studies reported that the diagnostic accuracy for GD vs. controls was approximately 90% (Higuchi et al., 2021; Yen et al., 2022). Unlike the DSM-5, the ICD-11 characterizes hazardous gaming (HG) as a gaming behavior pattern that increases the risk of harmful physical or mental health consequences without meeting the criteria for GD. HG was suggested to represent an earlier stage leading to GD (Kewitz, Leo, Rehbein, & Lindenberg, 2023). Therefore, identifying risk factors for HG and the progression from HG to GD is crucial for understanding the contributors to adverse outcomes in HG and loss of control over gaming in GD, respectively. However, no previous research has examined the factors associated with HG.

Psychiatric disorders comorbid with gaming disorder

Extensive research has consistently shown higher scores on psychiatric symptom scales assessing depression, anxiety, social anxiety, and ADHD among individuals with GD compared to controls (González-Bueso et al., 2018; Grassi, Moradei, & Cecchelli, 2024; Koncz et al., 2023; Torres-Rodríguez, Griffiths, Carbonell, & Oberst, 2018). However, survey studies have not concluded whether the severity of psychiatric symptoms reached clinical significance. Among individuals with IGD according to the DSM-5 criteria, previous studies have shown higher comorbid rates of ADHD (Martín-Fernández et al., 2016; Yen, Liu, et al., 2017), depressive disorder (Martín-Fernández et al., 2016), social anxiety disorder (SAD; Ko et al., 2021), and generalized anxiety disorder (GAD; Wang et al., 2017), based on psychiatric diagnoses. These studies support the association between psychiatric comorbidity and IGD.

IGD according to the DSM-5 is specified as being either mild, moderate, or severe, depending on the disruptions caused to daily life (APA, 2013). In the ICD-11, GD and hazardous gaming are differentially diagnosed based on severity and functional impairment (WHO, 2019). González-Bueso et al. (2020) classified clinical patients being treated for IGD ($N = 66$) based on cluster analysis. Their results demonstrated that there were 24 participants with "high comorbid symptoms" and 42 with "low comorbid symptoms". The same team subtyped clinical samples based on cluster analysis for psychiatric symptoms. Their results indicated that there was a higher ($n = 35$) and a lower psychological impact group ($n = 72$) (Granero et al., 2021). These studies suggest that psychiatric symptoms could be a critical factor in determining the severity of IGD. However, no prior studies have examined the psychiatric comorbidity with GD or HG based on the ICD-11 criteria in a psychiatric diagnostic interview among young adults.

Risk factors of gaming disorder

Meta-analyses have concluded that there are various risk factors for GD, including gender, impulsivity, depression, anxiety, stress, gaming time, escape motive (i.e., playing videogames to avoid facing everyday problems and difficulties), and low self-esteem (Király et al., 2022; Ropovik et al., 2023). The oversensitivity to positive rewards as well as imbalance in primary or secondary rewards have been reported among individuals with GD (Wang et al., 2021; Zhou et al., 2021). Neuroimaging studies and meta-analyses have reported the impairment of response inhibition among individuals with GD (Argyriou, Davison, & Lee, 2017; Ko et al., 2014). These reward and cognitive control system alterations might account for stronger gaming urges (Yen, Lin, Wu, & Ko, 2022) and uncontrolled gaming (Yen et al., 2022a). Furthermore, impaired emotion regulation (Yen, Yeh, et al., 2017) and dysfunctional coping (Lin et al., 2021) in relation to stress may be associated with depressed mood when functionally impaired due to GD. Many reviews have concluded that executive control, reward systems, and emotion regulation could be further essential domains that contribute to the development of GD (Dong & Potenza, 2014; Kuss et al., 2018; Weinstein & Lejoyeux, 2020). However, these three domains have not been examined

simultaneously in a single study to compare their effect. Furthermore, a multidimensional approach that covers cognitive control, emotion regulation, or reward vulnerability may assist individuals with GD (Ko, Király, Demetrovics, Chang, & Yen, 2020; Yen et al., 2023). However, if it is known which factor is important for HG, an earlier stage of GD, early treatment that fits the needs of individuals in this stage could be provided.

Therefore, the present case-control study aimed to explore whether the previously reported psychiatric comorbidities of GD based on the DSM-5 criteria are also more prevalent among GD or HG based on the ICD-11 criteria. Furthermore, the previously reported factors associated with GD or HG were also assessed. The present case-control study was designed to evaluate the (i) associative psychiatric comorbidities of GD and HG, including ADHD, depressive disorder, GAD, and SAD in comparison with controls; (ii) the association between cognitive performance, impulsivity, emotion regulation, and reinforcement sensitivity and GD and HG in comparison with controls; (iii) the difference in psychiatric comorbidity and cognitive performance, impulsivity, emotion regulation, and reinforcement sensitivity between individuals with GD and those with HG.

METHODS

Participants

Participants were recruited by posting an advertisement (see Appendix Table A1) on *Professional Technology Temple*, the most popular bulletin board system in Taiwan. Adults aged between 20 and 40 years who had completed upper secondary education were eligible to be interviewed for inclusion in the present case-control study. A psychiatrist determined whether participants had GD (Case group 1) or HG (Case group 2) using psychiatric interviewing based on the ICD-11 criteria as shown on the flow chart in Fig. 1. The details of the diagnostic interview were reported in a previous study (Yen et al., 2022). In addition, the Chinese version of the Mini International Neuropsychiatric Interview (Sheehan et al., 1998) was used to diagnose psychiatric comorbidity and exclude prospective participants with psychotic disorders, bipolar I disorder, or substance use disorder. The diagnosis of ADHD was confirmed based on the DSM-5 diagnostic criteria during the psychiatric interview. Moreover, an interview was conducted to exclude participants with intellectual disabilities or brain injuries. The duration of a psychiatric interview ranged from 30 to 90 min and varied depending on the complexity of the participant's condition.

The participants were categorized into either a GD, HG, or control group according to the ICD-11 criteria. Each participant with GD was matched with two gender-matched and age-matched (±3 years) controls. Participants who engaged in gaming with negative consequences but did not fulfill the diagnostic criteria for GD were included in the HG group. A financial incentive of 1,200 Taiwan New Dollars (approximately €35 or $38) was provided to participate in the present study.

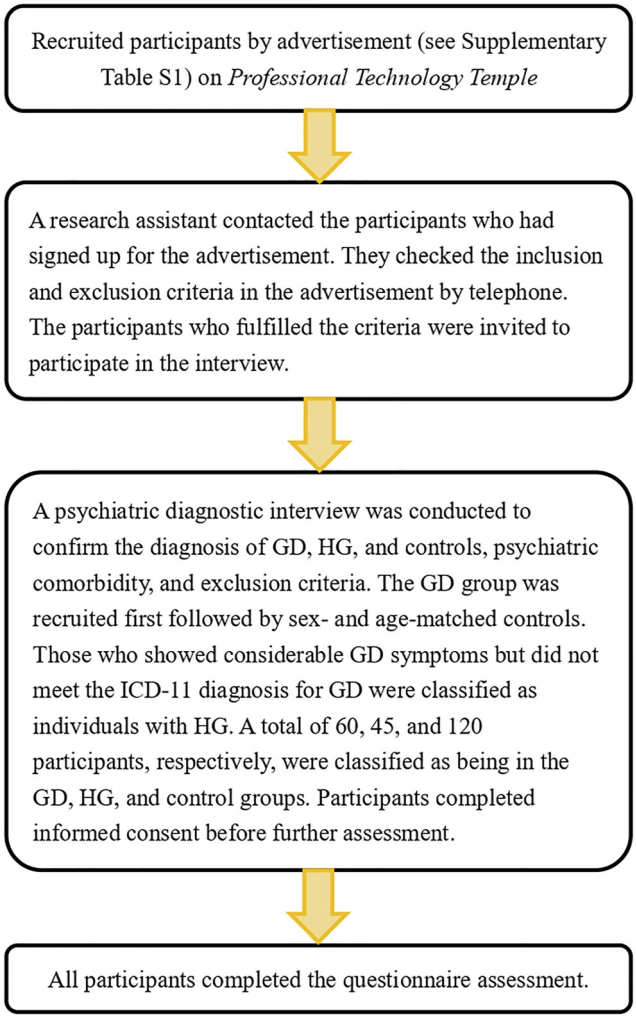

Fig. 1. Flow chart of participants' recruitment and study process. Figure legend: Individuals who did not fulfill the recruitment criteria were excluded from the study through telephone screening or diagnostic interviewing. The number of individuals who had signed up for the advertisement and who were excluded was not recorded. All 60, 45, and 120 participants in GD, HG, and control groups completed the questionnaire assessment. They were then evaluated by other assessments that were not analyzed in the present paper. GD = gaming disorder; HG = hazardous gaming; ICD-11 = 11th revision of the International Classification of Disease

The GD, HG, and control groups had 60, 45, and 120 participants, respectively. All participants provided their written informed consent before they completed all measures (outlined in the next section), as outlined in Fig. 1.

Measures

Chinese version of the Mini International Neuropsychiatric Interview (C-MINI): The C-MINI (Sheehan et al., 1998) was used to determine whether the participants had depressive disorder, generalized anxiety disorder (GAD), and/or social

anxiety disorder (SAD) and to exclude other psychiatric disorders, such as psychotic disorders, bipolar I disorder, and substance use disorder. Participants with a depressive episode, persistent depressive disorder, or depressive episode history were assigned to the depressive disorder group.

Conners' Continuous Performance Test 3rd Edition (CCPT): Conners et al. (2014) developed the computerized CCPT to evaluate attention-related and inhibitory-control problems for individuals with ADHD. In the present study, participants were instructed to press the space bar on a computer as fast as possible when a letter other than an "X" was displayed (go trials) on screen but to inhibit that response when an "X" was shown (no-go trials). The inter-stimulus interval changed between 1, 2, or 4 s every 20 trials. There were 361 trials, with 80% go trials and 20% no-go trials. The scoring of the Conners CPT 3 is based on omission errors (missed targets), commission errors (incorrect responses to non-targets), perseverations (responses made in less than 100 ms following a stimulus), and detectability (discrimination between non-targets and targets).

Dickman's Impulsivity Inventory (Dickman, 1990): The inventory comprises 23 true/false items used which are used to assess impulsivity consisting of functional impulsivity (11 items; e.g., *"Most of the time, I can put my thoughts into words very rapidly"*) and dysfunctional impulsivity (12 items; e.g., *"I often get into trouble because I don't think before act"*). Participants answer each item as either true or false, and the total score ranges from 0 (low) to 11 (high) and from 0 (low) to 12 (high) for functional impulsivity and dysfunctional impulsivity, respectively. The higher the score, the higher the functional or dysfunctional impulsivity. Impulsivity was assessed by dysfunctional impulsivity subscale, and the Cronbach's alpha in the present study was 0.80.

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003): The ERQ is a 10-item scale designed to assess an individual's tendency to regulate their emotions across two domains: cognitive reappraisal assessed using the reappraisal scale (six items; e.g., *"I control my emotions by changing the way I think about the situation I'm in"*), and expressive suppression assessed using the suppression scale (four items: e.g., *"I control my emotions by not expressing them"*). Participants answer each item on a seven-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) and the total score ranges from 6 to 42 (reappraisal subscale) and 4 to 28 (expressive suppression subscale). Higher scores indicate a high tendency to regulate emotions by using reappraisal or suppression. In the present study, the Cronbach's alphas of the reappraisal and suppression subscales were 0.86 and 0.64, respectively.

Behavior Inhibition System and Behavior Approach System Scales (BIS/BAS Scales): The BIS/BAS Scales (Carver & White, 1994) were designed to assess individual differences in the reinforcement sensitivity of the two motivational systems, BIS and BAS, proposed by Gray (Corr, 2004). The BIS Scale (seven items; e.g., *"I worry about making mistakes"*) assesses the degree to which participants expect to feel anxiety when confronted with cues for punishment (i.e., aversion sensitivity). The BAS Scale includes subscales of reward responsiveness (five items; e.g., *"It would excite me to win a contest"*), drive (four items; e.g., *"I go out of my way to get things I want"*), and fun-seeking (four items; e.g., *"I crave excitement and new sensations"*), which assess the degree to which rewards lead to positive emotions, a person's tendency to actively pursue appetitive goals, and the tendency to seek out and impulsively engage in potentially rewarding activities respectively (i.e., reward sensitivity). Participants answer each item on a four-point scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) and the total scores range from 4 to 28 (BIS), 4 to 20 (reward responsiveness), 4 to 16 (drive), and 4 to 16 (fun-seeking). Higher BIS and BAS subscale scores indicate greater aversion sensitivity and reward sensitivity, respectively. In the present study, the Cronbach's alphas were 0.76 for BIS, 0.75 for drive, 0.53 for fun-seeking, and 0.78 for reward responsiveness.

Statistical analysis

Chi-square tests were used to evaluate the associations between ADHD, depressive disorder, GAD, SAD, and GD. The odds ratio of GD versus controls, HG versus controls, and GD versus HG for psychiatric comorbidity were analyzed using logistic regression and adjusted for gender and age to minimize their residual confounding effect (Pearce, 2016). Analyses of covariance (ANCOVA) with Bonferroni post hoc tests were conducted to evaluate differences in age, educational level, performance in CCPT, and scores on impulsivity, emotion regulation, and reinforcement sensitivity among the GD, HG, and control groups while controlling for gender and age. Logistic regression using the enter method was performed to evaluate the association between psychiatric comorbidities or risk factors and GD versus controls while controlling for gender and age. The same analyses were also used to compare HG group versus controls as well as GD group versus HG group. Results with $p < 0.05$ were considered significant in all analyses, which were performed using IBM SPSS Statistics (Version 26).

Ethics

The study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital, Taiwan, and ran from May 2019 to October 2020.

RESULTS

There were no significant differences in age, gender, and educational level between the GD group, HG group, and control group (Table 1). Approximately one-quarter of the GD group comprised females (23.3%), compared to 31.1% in the HG group and 23.3% in the control group. The mean ages were 26.4 years (GD group), 26.6 years (HG group), and 27.2 years (control group).

Table 1. Demographic data, psychiatric disorders, and risk factors in the three groups

Variable	Gaming disorder group (N = 60) N (%)/Mean (SD)	Hazardous gaming group (N = 45) N (%)/Mean (SD)	Control group (N = 120) N (%)/Mean (SD)	χ^2	Pairwise group comparisons (odds ratio [95% CI])
Gender					
Female	14 (23.3)	14 (31.1)	28 (23.3)	1.17	GD vs Control (Male: 1.00 [0.48; 2.08]);
Male	46 (76.7)	31 (68.9)	92 (76.7)		GD vs HG (Male: 1.48 [0.62; 3.54]);
					HG vs Control (Male: 0.67 [0.32; 1.44]);
ADHD					
Yes	32 (53.3)	15 (33.3)	8 (6.7)	49.57***	GD vs Control (16.00† [6.61; 38.75]);
No	28 (46.7)	30 (66.7)	112 (93.3)		GD vs HG (2.42† [1.07; 5.48]);
					HG vs Control (6.81† [2.63; 17.63]);
Depressive disorders					
Yes	22 (36.7)	3 (6.7)	6 (5.0)	36.16***	GD vs Control (11.47† [4.28; 30.74]);
No	38 (63.3)	42 (93.3)	114 (95.0)		GD vs HG (8.09† [2.23; 29.35]);
					HG vs Control (1.36† [0.32; 5.73]);
Generalized Anxiety Disorder					
Yes	18 (30.0)	7 (15.6)	5 (4.2)	23.34***	GD vs Control (10.33† [3.52; 30.31]);
No	42 (70.0)	38 (84.4)	115 (95.8)		GD vs HG (2.49† [0.92; 6.77]);
					HG vs Control (4.15† [1.24; 13.92]);
Social Anxiety Disorder					
Yes	5 (8.3)	1 (2.2)	2 (1.7)	5.48	GD vs Control (5.74† [1.02; 32.27]);
No	55 (91.7)	44 (97.8)	118 (98.3)		GD vs HG (6.18† [0.64; 60.00]);
					HG vs Control (1.12† [0.10; 13.02]);
				F	Bonferroni post-hoc tests (Cohen's d††)
Age (range 20–40 years)	26.42 (4.54)	26.60 (5.00)	27.18 (4.56)	0.58	Control>GD (0.17); HG>GD (0.08); Control>HG (0.08)
Educational level (years)	15.80 (1.36)	15.73 (1.57)	16.02 (1.68)	0.59	Control>GD (0.12); GD>HG (0.05); Control>HG (0.17)
CCPT performance					
Detectability	48.32 (10.17)	47.20 (9.62)	46.71 (9.55)	0.63	GD>Control (0.18); GD>HG (0.15); HG>Control (0.03)
Omissions	46.25 (6.32)	45.98 (5.00)	45.97 (5.15)	0.08	GD>Control (0.05); GD>HG (0.07); Control>HG (0.02)
Commissions	51.77 (11.14)	50.18 (11.20)	49.53 (10.66)	0.97	GD>Control (0.22); GD>HG (0.18); HG>Control (0.04)
Perseverations	49.90 (10.26)	47.02 (3.64)	47.10 (3.89)	4.66*	GD>Control (0.44*); GD>HG (0.50*); Control>HG (0.06)
Impulsivity	5.35 (3.27)	4.42 (3.12)	3.35 (2.87)	8.50***	GD>Control (0.64***); GD>HG (0.30); HG>Control (0.34)
Functional Impulsivity	5.25 (3.15)	5.56 (3.57)	6.26 (2.89)	2.25	Control>GD (0.32); HG>GD (0.12); Control>HG (0.21)
Reappraisal	29.42 (5.55)	31.47 (5.92)	33.86 (5.09)	14.69***	Control>GD (0.85***); HG>GD (0.42); Control>HG (0.43*);
Suppression	19.07 (4.38)	18.31 (4.32)	18.35 (4.03)	0.62	GD>Control (0.17); GD>HG (0.16); HG>Control (0.01)
Aversion sensitivity	22.65 (2.86)	21.71 (3.58)	20.03 (3.08)	14.55***	GD>Control (0.83***); GD>HG (0.32); HG>Control (0.50**);
Drive	12.10 (2.07)	12.38 (1.79)	12.99 (1.91)	4.65*	Control>GD (0.46*); HG>GD (0.17); Control>HG (0.30)
Fun-seeking	12.15 (2.18)	12.56 (1.60)	11.56 (1.78)	5.19**	GD>Control (0.30); HG>GD (0.24); HG>Control (0.54**)
Reward Responsiveness	17.63 (2.18)	17.42 (1.84)	17.30 (2.03)	0.45	GD>Control (0.15); GD>HG (0.09); HG>Control (0.06)

Note:
GD: gaming disorder; HG: hazardous gaming; Control: control group.
ADHD: Attention Deficit Hyperactivity Disorder.
Depressive disorder: Individuals with a major depressive episode, history of major depressive episodes, or persistent depressive disorder.
CCPT: Conners' Continuous Performance Test 3rd Edition.
F: *F* value of analysis of covariance (ANCOVA) with control of gender and age.
Data are unadjusted mean ± standard deviation.
† Odds ratio adjusted for gender and age.
†† Cohen's *d* values were calculated from the adjusted mean values and standard errors.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Psychiatric comorbidity of GD

Adult ADHD was diagnosed in 53.3% of the GD group, 33.3% of the HG group, and 6.7% of the control group (χ^2 = 49.57; p < 0.001). Participants with ADHD had a higher odds ratio of 16.00 (95% CI [6.61, 38.75]) for having GD and a higher odds ratio of 6.81 (95% CI [2.63, 17.63]) for having HG compared to controls (Table 1). Additionally, 36.7% of the GD group, 6.7% of the HG group, and 5.0% of the control group were diagnosed as having a depressive episode, persistent depressive disorder, or depression history (χ^2 = 36.16; p < 0.001). Participants having a depressive episode, depressive disorder or depression history had a higher odds ratio of 11.47 (95% CI [4.28, 30.74]) for having GD (Table 1). Moreover, 30% of the GD group, 15.6% of the HG group, and 4.2% of the control group were diagnosed with GAD (χ^2 = 23.34; p < 0.001). Participants with GAD had a higher odds ratio of 10.33 (95% CI [3.52, 30.31]) for having GD and a higher odds ratio of 4.15 (95% CI [1.24, 13.92]) for having HG compared to controls (Table 1). Last, 8.3% of the GD group, 2.2% of the HG group, and 1.7% of controls were diagnosed with SAD (χ^2 = 5.48; p = 0.07). Participants with SAD had a higher odds ratio of 5.74 (95% CI [1.02, 32.27]) for having GD compared to controls.

The model regressing GD on psychiatric comorbidity was statistically significant, χ^2 = 79.04, p < 0.001 (Model 1 in Table 2). It explained 49.4% of the variance in GD (Nagelkerke R^2) and correctly classified 82.2% of participants. Adult ADHD (odds ratio = 13.15, 95% CI = 4.98–34.71), depressive disorder (odds ratio = 8.04, 95% CI = 2.61–24.76), and GAD (odds ratio = 5.16, 95% CI = 1.41–18.95) were significant predictors in the model.

The similar model for HG relative to controls was statistically significant, χ^2 = 21.30, p = 0.002 (Model 1 in Table 3). The model explained 17.5% of the variance in HG (Nagelkerke R^2) and correctly classified 76.4% of participants. Only adult ADHD was a significant predictor in the model (odds ratio = 6.35, 95% CI = 2.40–16.77). Those with adult ADHD were 6.35 times more likely to be diagnosed with HG than those without adult ADHD (95% CI = 2.40–16.77).

The similar model for GD relative to HG was statistically significant, χ^2 = 22.87, p = 0.001(Model 1 in Table 4). The model explained 26.3% of the variance in GD (Nagelkerke R^2) and correctly classified 67.6% of participants. Depressive disorders were the only significant predictors in the model (odds ratio = 7.51, 95% CI = 2.01–28.04).

The CCPT performance, impulsivity, emotion regulation, and reinforcement sensitivity of gaming disorder and hazardous gaming

The ANCOVA in Table 1 shows there were significant differences in perseverations ($F_{2,1,1,220}$ = 4.66, p = 0.01), impulsivity ($F_{2,1,1,220}$ = 8.50, p < 0.001), reappraisal ($F_{2,1,1,220}$ = 14.69, p < 0.001), aversion sensitivity ($F_{2,1,1,220}$ = 14.55, p < 0.001), drive ($F_{2,1,1,220}$ = 4.65, p = *0.01*), and fun-seeking ($F_{2,1,1,220}$ = 5.19, p = 0.01) between the GD, HG, and control groups. The Bonferroni post hoc analysis found that compared to controls, participants with GD had significantly higher (i) perseverations (Cohen's d = 0.44), (ii) impulsivity (Cohen's d = 0.64), and (iii) aversion sensitivity (Cohen's d = 0.83), and significantly lower (i) reappraisal (Cohen's d = 0.85), and (ii) drive (Cohen's d = 0.46).

The logistic regression model regressing GD on the aforementioned factors was statistically significant, χ^2 = 74.80, p < 0.001 (Model 2 in Table 2). The model explained 47.2% of the variance in GD (Nagelkerke R^2) and correctly classified 80.6% of participants. Increasing reappraisal score (OR = 0.87, 95% CI = 0.80–0.94) or BAS drive score (OR = 0.69, 95% CI = 0.52–0.92) were associated with a reduction in the likelihood of being diagnosed with GD. Increasing aversion sensitivity (OR = 1.30, 95% CI = 1.10–1.53), impulsivity (OR = 1.20, 95% CI = 1.04–1.39), and perseverations (OR = 1.09, 95% CI = 1.00–1.39) were associated with an increased likelihood of being diagnosed with GD.

Table 2. Logistic regression evaluating the association between psychiatric disorders, risk factors, and gaming disorder (GD) adjusted for gender and age

GD versus controls	Wald χ^2	Odds ratio (95% CI)
Model 1: Psychiatric comorbidity		
Gender	2.20	2.45 (0.75–8.00)
Age	0.39	0.97 (0.89–1.07)
Adult ADHD	27.07***	13.15 (4.98–34.71)
Depressive disorder	13.18***	8.04 (2.61–24.76)
Generalized anxiety disorder	6.12*	5.16 (1.41–18.95)
Social anxiety disorder	2.79	6.68 (0.72–61.98)
Chi-square test: 79.04***; Nagelkerke R^2 = 49.4%		
Model 2: Risk factors		
Gender	3.41	2.77 (0.94–8.14)
Age	0.01	1.00 (0.91–1.10)
CCPT performance		
Detectability	1.88	0.88 (0.73–1.06)
Omissions	0.56	1.05 (0.92–1.20)
Commissions	1.46	1.09 (0.95–1.24)
Perseverations	4.14*	1.09 (1.00–1.19)
Impulsivity	5.89*	1.20 (1.04–1.39)
Functional impulsivity	0.12	0.97 (0.83–1.14)
Reappraisal	11.48**	0.87 (0.80–0.94)
Suppression	0.49	1.04 (0.94–1.15)
Aversion sensitivity	9.40**	1.30 (1.10–1.53)
Drive	6.46*	0.69 (0.52–0.92)
Fun-seeking	0.24	1.07 (0.82–1.38)
Reward responsiveness	1.71	1.21 (0.91–1.62)
Chi-square test: 74.80*** Nagelkerke R^2 = 47.2%		

Note:
GD: gaming disorder; Controls: control group.
ADHD: Attention Deficit Hyperactivity Disorder.
Depressive disorder: Individuals with a major depressive episode, history of major depressive episodes, or persistent depressive disorder.
CCPT: Conners' Continuous Performance Test 3rd Edition.
95% CI = 95% Confidence Interval; Wald χ^2 = chi-square test.
*p < 0.05, **p < 0.01, ***p < 0.001.

Table 3. Logistic regression evaluating the association between psychiatric disorders, risk factors, and hazardous gaming (HG) adjusted for gender and age

HG versus controls	Wald χ^2	Odds ratio (95% CI)
Model 1: Psychiatric comorbidity		
Gender	0.27	0.80 (0.34–1.88)
Age	0.15	0.98 (0.91–1.07)
Adult ADHD	13.90***	6.35 (2.40–16.77)
Depressive disorder	0.18	1.40 (0.30–6.59)
Generalized anxiety disorder	0.01	3.29 (0.89–12.09)
Social anxiety disorder	0.53	0.90 (0.06–13.16)
Chi-square test: 21.30** Nagelkerke R^2 = 17.5%		
Model 2: Risk factors		
Gender	0.17	0.82 (0.31–2.13)
Age	0.01	1.01 (0.92–1.10)
CCPT performance		
Detectability	0.21	1.04 (0.89–1.22)
Omissions	0.49	0.96 (0.84–1.09)
Commissions	0.25	0.97 (0.86–1.09)
Perseverations	0.00	1.00 (0.88–1.15)
Impulsivity	0.03	1.01 (0.87–1.18)
Functional impulsivity	0.00	1.00 (0.86–1.15)
Reappraisal	3.12	0.93 (0.87–1.01)
Suppression	0.32	1.03 (0.93–1.14)
Aversion sensitivity	3.14	1.15 (0.99–1.35)
Drive	4.61*	0.74 (0.56–0.97)
Fun-seeking	9.94**	1.60 (1.20–2.15)
Reward responsiveness	0.02	0.98 (0.75–1.29)
Chi-square test: 31.03** Nagelkerke R^2 = 24.9%		

Note:
HG: hazardous gaming; Controls: control group.
ADHD: Attention Deficit Hyperactivity Disorder.
Depressive disorder: Individuals with a major depressive episode, history of major depressive episodes, or persistent depressive disorder.
CCPT: Conners' Continuous Performance Test 3rd Edition.
95% CI = 95% Confidence Interval; Wald χ^2 = chi-square test.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The Bonferroni post hoc analysis also found that the HG group had significantly higher aversion sensitivity (Cohen's $d = 0.50$) and fun-seeking (Cohen's $d = 0.54$) and lower reappraisal (Cohen's $d = 0.43$) than the controls (Table 1). The logistic regression model for HG relative to controls was statistically significant, $\chi^2 = 31.03$, $p = 0.005$ (Model 2 in Table 3). The model explained 24.9% of the variance in HG (Nagelkerke R^2) and correctly classified 75.2% of participants. Increasing BAS fun-seeking (OR = 1.56, 95% CI = 1.22–1.99) was associated with an increased likelihood of being diagnosed with HG. Increasing BAS drive score was associated with reducing the likelihood of being diagnosed with HG (OR = 0.74, 95% CI = 0.56–0.97).

DISCUSSION

The present case-control study, using diagnostic interviews, demonstrated comorbidities with attention deficit hyperactivity disorder (ADHD), depressive disorder, and general anxiety disorder (GAD) among adults with gaming disorder (GD) or hazardous gaming (HG) based on the ICD-11 criteria similar to previous reports for IGD in DSM-5 (Ko et al., 2021; Martín-Fernández et al., 2016; Wang et al., 2017; Yen, Liu, et al., 2017). Individuals with GD had higher impulsivity, lower emotion regulation, and higher aversion sensitivity than controls which concurs with previous studies (Lin, Lin, Lin, Yen, & Ko, 2020; Wang et al., 2017; Yen, Liu, et al., 2017). On the other hand, individuals with HG had higher fun-seeking and lower BAS drive than controls.

Table 4. Logistic regression evaluating the association between psychiatric disorders, risk factors, and gaming disorder (GD) in comparison with Hazardous gaming (HG) adjusted for gender and age

GD versus HG	Wald χ^2	Odds ratio (95% CI)
Model 1: Psychiatric comorbidity		
Gender	2.11	2.23 (0.75–6.62)
Age	0.03	1.01 (0.92–1.11)
Adult ADHD	3.71	2.39 (0.98–5.81)
Depressive disorder	9.00**	7.51 (2.01–28.04)
Generalized anxiety disorder	1.58	2.00 (0.68–5.90)
Social anxiety disorder	1.32	4.38 (0.35–54.57)
Chi-square test: 22.87** Nagelkerke R^2 = 26.3%		

Note:
GD: gaming disorder; HG: hazardous gaming.
ADHD: Attention Deficit Hyperactivity Disorder.
Depressive disorder: Individuals with a major depressive episode, history of major depressive episodes, or persistent depressive disorder.
95% CI = 95% Confidence Interval; Wald χ^2 = chi-square test.
**$p < 0.01$.

Comorbidity with ADHD and impulsivity among individuals with gaming disorder

ADHD is one of the most reported comorbid psychiatric disorders of GD (Dullur, Krishnan, & Diaz, 2021; González-Bueso et al., 2018; Koncz et al., 2023, 2024; Wang, Yin, Wang, King, & Rost, 2024; Werling, Kuzhippallil, Emery, Walitza, & Drechsler, 2022). ADHD has consistently been reported to be frequently comorbid with GD, ranging from 39% to 50.7% among individuals with GD (Cabelguen et al., 2021; Ko et al., 2021; Yen, Liu, et al., 2017). According to a recent meta-analysis, in studies where individuals with and without a GD diagnosis were compared, a large positive difference ($g = 0.854$, $p < 0.001$) was found regarding ADHD symptom severity (Koncz et al., 2023). Furthermore, adult ADHD was the comorbid psychiatric disorder most associated with GD in the logistic regression analysis in the present study, as was found in a previous study for IGD (Ko et al., 2021). This result suggests that ADHD is also prevalent among individuals with GD based on the ICD-11 criteria, which emphasizes uncontrolled gaming with high priority and has a higher intensity threshold than the DSM-5 criteria of IGD (Yen et al., 2023).

The present study also demonstrated that the GD group had higher impulsivity and perseveration than the controls. According to the definition of Dickman's Impulsivity Inventory, dysfunctional impulsivity results in rapid and inaccurate performance with a rapid and error-prone information-processing pattern rather than deliberative thinking (Dickman, 1990). Perseveration indicates impairment in extinguishing a previously rewarded response (Ribes-Guardiola, Poy, Segarra, Branchadell, & Moltó, 2020). Lack of deliberation and difficulty in extinguishing an established rewarded response may make individuals with GD unable to control their gaming behavior and may cause negative consequences. This finding is in line with previous studies that reported that impulsivity and low conscientiousness were risk factors associated with GD (Gentile et al., 2011; Muller, Dreier, & Wolfling, 2023).

Previous reviews have demonstrated a consistent positive association between impulsivity and GD (Şalvarlı & Griffiths, 2022), which may be due to an altered neurobiological structure among individuals with impulsivity, as a previous study suggested regarding its role in biomarkers (Zhang et al., 2023). Impulsivity has also been shown to mediate the association between the catechol-O-methyltransferase polymorphism and GD (Yen, Lin, et al., 2022). The possible role of impulsivity in the vulnerability of GD might account for the higher impulsivity of GD in the present study.

Impulsivity is the core symptom in the diagnostic criteria of ADHD (APA, 2013). Moreover, higher perseveration is one of the neuropsychological characteristics of ADHD (Rizzutti et al., 2015). Previous studies reported that individuals with GD and ADHD have higher impulsivity and lower self-control than controls (Ko et al., 2021). Impulsivity has also been reported to have an essential role in the association between ADHD and GD in several studies (Cabelguen et al., 2021; Ko et al., 2021; Yen, Liu, et al., 2017). The high comorbidity with ADHD might also contribute to the higher impulsivity and perseveration of GD in the present study.

In the present study, 53.3% of the GD group (n = 32) were diagnosed with adult ADHD. Comorbid ADHD could affect the clinical course or treatment response among individuals with GD. Martín-Fernández et al. (2016) demonstrated a favorable treatment response at three and six months among adolescents with IGD and externalizing profiles, including ADHD. However, Lee, Bae, Kim, and Han (2021) reported that ADHD comorbidity was associated with poor treatment outcomes among those aged 11–42 years, after eight weeks of treatment after three years of follow-up. Previous intervention studies suggest that treating the underlying symptoms of ADHD significantly improves the symptoms of GD (Chang, Chang, Cheng, & Tzang, 2020). Therefore, ADHD and impulsivity should be evaluated and effectively treated among individuals with GD.

Depression and emotion regulation among individuals with gaming disorder

Previous studies have reported the association between depressive disorder and GD in both diagnostic interviewing (Ko et al., 2021) and survey studies (Ropovik et al., 2023; Teng, Pontes, Nie, Griffiths, & Guo, 2021). In the present study, the logistic regression indicated that those with depressive disorder were 8.04 times (95% CI = 2.61–24.76) more likely to be diagnosed with GD than those without depressive disorder. This result suggests that individuals with depressive disorder are more prone to have GD than those without depressive disorder. Furthermore, higher reappraisal scores were associated with a reduced likelihood of being diagnosed with GD versus controls (OR = 0.87; 95%CI = 0.80–0.94). Previous studies have reported lower emotion regulation among individuals with GD (Kökönyei et al., 2019; Lin et al., 2020; Yen et al., 2017). A recent study suggested that immersion/escapism motivation mediated the association between depressive symptoms and gaming disorder symptoms (Király et al., 2022). Therefore, individuals experiencing depressive symptoms may have a higher motivation to play games to escape/avoid everyday problems and difficulties. Lower reappraisal and dysfunctional coping (Lin et al., 2021) associated with GD might make it challenging for gamers to improve their mood by themselves. Without effective intervention to alleviate depression and promote coping, gaming to escape might result in negative consequences, which results in a vicious cycle.

Generalized anxiety disorder, social anxiety disorder, and aversion sensitivity among individuals with gaming disorder

GAD and SAD were associated with GD in the pairwise group comparison analyses. However, only GAD, but not SAD, was associated with GD when other psychiatric disorders were controlled for. Those with GAD were 5.16 times more likely to have GD than those without GAD, which concurs with the findings of previous studies (Ko et al., 2021; Wang et al., 2017). Moreover, aversion sensitivity – which represents hypersensitivity to punishment and non-reward (Carver & White, 1994) – was associated with GD in the present study, which aligns with a previous study (Xiang et al., 2020). Previous studies demonstrated that individuals with GAD have higher aversion sensitivity (Akdeniz Gorgulu, Baykan, & Karlidere, 2023) and that aversion sensitivity confounded the association between GAD and GD (Wang et al., 2017). Individuals with GAD can experience chronic and long-term anxiety in their daily lives. They may engage in gaming to escape their worries and meet others virtually which may lower their social anxiety (Hutchins, Allen, Curran, & Kannis-Dymand, 2021). The sensitivity to aversion and non-reward might reinforce their gaming behavior to escape from stress and anxiety in daily life. However, gaming to escape may increase the risk of GD (Bäcklund, Elbe, Gavelin, Sörman, & Ljungberg, 2022; Melodia, Canale, & Griffiths, 2022; Ropovik et al., 2023).

Individuals with GD may experience negative consequences (Ko, Lin, Lin, & Yen, 2020) that lead to stress and drive them to limit their gaming. However, if they try to control gaming without adequate resources, they may experience withdrawal-related symptoms such as irritability,

craving, and/or anhedonia (Yen et al., 2022). Their sensitivity to these aversive experiences might prevent them from controlling their gaming. Their high aversion sensitivity might also prevent them from trying alternative activities. The aforementioned interplay between GAD and aversion sensitivity in the course of GD requires additional prospective studies, specifically on GD with GAD. Moreover, individuals with GD should be evaluated for GAD and aversion sensitivity to provide effective intervention for them.

Psychiatric comorbidity and risk factors of hazardous gaming

The present study is the first to show that adult ADHD is the psychiatric comorbidity most associated with HG, a potential early stage of GD (Kewitz et al., 2023). Therefore, intervention for ADHD might benefit not only those who have GD (Han et al., 2009) but also those who have HG and experience some level of harm due to their gaming activity. The present study also demonstrated that individuals with HG have greater fun-seeking than controls. Previous research has reported an association between fun-seeking and GD in genetic and brain imaging studies (Dong, Zheng, Wang, Ye, & Dong, 2022; Yen et al., 2022b). Fun-seeking refers to a desire for a new reward and a willingness to approach a potentially rewarding event (Carver & White, 1994). Therefore, individuals with high fun-seeking could have a higher desire to engage in gaming, and the rewarding design of games could reinforce their desire. Stronger desire without control might be associated with health risks, such as decreased or worse sleep. Moreover, BAS drive was negatively associated with HG in the regression analysis. Drive represents the persistent pursuit of a desired goal (Carver & White, 1994), such as *"I go out of my way to get things I want."* Although individuals with higher drive could have higher motivation for gaming, they could also be motivated by their goals in daily life instead. The motivation to take action for their desired goals may contribute to good functioning in daily life. Therefore, promoting engagement in alternative recreational activities to satisfy reward sensitivity in fun-seeking or redefining their goals in daily life to empower their drive to act on them is crucial in preventing HG, particularly for those with ADHD.

The difference in psychiatric comorbidity between GD and HG group

The ICD-11 criteria of GD and HG make it possible to have a comparison between the early and late stages of addiction to gaming. Both ADHD and depressive disorder were associated with the GD group in comparison with the HG group. When all psychiatric comorbidities entered the model, depressive disorder remained the only significant factor associated with GD. It showed that patients with GD had significantly higher depression than patients with HG. This indicates that depression is a key (or an important factor to be considered) when differentiating GD from HG in the diagnostic phase. Gentile et al. (2011) suggested that GD contributes to depression in a prospective study. Individuals with GD experience functional impairment caused by gaming but are still unable to control their behavior. This frustrating experience might further increase their depression symptoms and explain the higher depression rate among GD patients compared to those with HG.

Clinical implications

Previous reviews have suggested that cognitive control, emotional regulation, and reward sensitivity contribute to GD based on the neurobiological or cognitive behavior model (Dong & Potenza, 2014; Kuss et al., 2018; Weinstein & Lejoyeux, 2020). The present study's findings suggest that impulsivity, perseveration, emotional regulation, and aversion sensitivity are associated with GD. Individuals with GD have a higher comorbid rate of ADHD, depressive disorder, and GAD than controls. These multifaceted factors may complexly reinforce and exacerbate one another and contribute to different stages of GD. For example, ADHD and fun-seeking were associated with HG, a possible early stage of GD, and depression was associated with GD relative to HG. Additional studies to understand the complex interplay of risk factors and comorbidity for GD or HG, such as escapism in the association between ADHD and GD (Koncz et al., 2024), are necessary. They have important implications for clinical work. Comprehensive assessments addressing these essential domains and psychiatric comorbidities are also required to develop an individualized, integrated treatment to fit the personal needs of individuals with GD or HG.

LIMITATIONS

The present study has some limitations. First, due to the nature of being a case-control study, the direction of the associations between GD and psychiatric disorders cannot be determined. Second, symptoms of depression and social anxiety may have prevented some individuals with SAD or major depressive disorder from participating in the study. However, this effect would be equal in both the GD and control groups. Third, the present study did not demonstrate a significant association between GD and SAD in control of other psychiatric disorders, even though participants with SAD had a higher odds ratio of 5.74 (95% CI [1.02, 32.27]) for having GD compared to the controls. The low number of cases of social anxiety might have limited the power to detect a significant difference. Fourth, Cronbach's alpha values of the fun-seeking subscale of the BIS/BAS scale were below 0.6. The low number of items (i.e., four items) might be associated with the low Cronbach's alpha as was reported in the original study (Carver & White, 1994). Lastly, the number of those initially contacted and excluded from the study was not recorded in the telephone screening or diagnostic interviewing. Therefore, it cannot be confirmed

whether the exclusion criteria contributed to bias in case recruitment. However, all participants completed the questionnaires without dropping out during the evaluation stage.

CONCLUSION

The present case-control diagnostic interview study demonstrated the psychiatric comorbidity of ADHD, depressive disorder, and GAD among individuals with GD based on the ICD-11 criteria. ADHD, depressive disorder, and GAD should be evaluated and treated among individuals with GD. Higher impulsivity, aversion sensitivity, and lower reappraisal were also associated with GD. Intervention for these risk factors should be included in the treatment plan for GD. ADHD was also associated with HG, and depressive disorder was associated with GD relative to HG. ADHD should be intervened as early as possible, which might prevent HG. The effects of the suggested treatments should be studied in future intervention studies.

Funding sources: The present study was supported by the Ministry of Science and Technology, Taiwan (MOST110-2314-B-037-062-, MOST111-2314-B-037-036, and NSTC112-2314-B-037-040-MY3), and Kaohsiung Municipal Siaogang Hospital (H-109-004, kmhk H-110-06, and kmhk H-111-03). ZD's contribution was supported by the Hungarian National Research, Development and Innovation Office (KKP126835). These institutions had no role in the study design, collection, analysis, or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Authors' contribution: JYY wrote the original manuscript, derived the models, and analyzed the data. CHK reviewed the final manuscript in consultation with MDG, ZD, and OK. MDG, ZD, and OK reviewed the original manuscript, edited the style and English, and provided opinions in discussion and analysis. CHK supervised the study and administrated the research planning and execution.

Conflict of interests: The authors declare that they have no conflicts of interest related to the present study. ZD is the Editor-in-Chief of the *Journal of Behavioral Addictions*. The University of Gibraltar received funding from the Gibraltar Gambling Care Foundation, an independent, not-for-profit charity, and donations from gambling operators through the LCCP RET process supervised by the UK Gambling Commission. MDG has received research funding from *Norsk Tipping* (the gambling operator owned by the Norwegian government). MDG has received funding for a number of research projects in the area of gambling education for young people, social responsibility in gambling and gambling treatment from *Gamble Aware* (formerly the *Responsibility in Gambling Trust*), a charitable body which funds its research program based on donations from the gambling industry. MDG undertakes consultancy for various gambling companies in the area of player protection and social responsibility in gambling.

LIST OF ABBREVIATIONS

ADHD	Attention deficit hyperactivity disorder
ANOVA	Analysis of variance
APA	American Psychiatric Association
BIS/BAS	Behavior Inhibition System and Behavior Approach System
CCPT	Conners' Continuous Performance Test 3rd Edition
C-MINI	Chinese version of the Mini International Neuropsychiatric Interview
DSM-5	The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders
GAD	Generalized anxiety disorder
GD	Gaming disorder
HG	Hazardous gaming
ICD-11	The 11th revision of the International Classification of Diseases
IGD	Internet gaming disorder
SAD	Social anxiety disorder
WHO	World Health Organization

REFERENCES

Akdeniz Gorgulu, S., Baykan, H., & Karlidere, T. (2023). Correlation among experiential avoidance, anxiety sensitivity and behavioral inhibition system in generalized anxiety disorder and panic disorder patients. *Psychiatria Danubina*, *35*(3), 344–354. https://doi:10.24869/psyd.2023.344.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing, Inc.

Argyriou, E., Davison, C. B., & Lee, T. T. C. (2017). Response inhibition and internet gaming disorder: A meta-analysis. *Addictive Behaviors*, *71*, 54–60. https://doi.org/10.1016/j.addbeh.2017.02.026.

Bäcklund, C., Elbe, P., Gavelin, H. M., Sörman, D. E., & Ljungberg, J. K. (2022). Gaming motivations and gaming disorder symptoms: A systematic review and meta-analysis. *Journal of Behavioral Addictions*, *11*(3), 667–688. https://doi.org/10.1556/2006.2022.00053.

Cabelguen, C., Rocher, B., Leboucher, J., Schreck, B., Challet-Bouju, G., Hardouin, J.-B., & Grall-Bronnec, M. (2021). Attention deficit hyperactivity disorder and gaming disorder: Frequency and associated factors in a clinical sample of patients with gaming disorder. *Journal of Behavioral Addictions*, *10*(4), 1061–1067. https://doi.org/10.1556/2006.2021.00074.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of*

Personality and Social Psychology, *67*, 319–333. https://doi.org/10.1037/0022-3514.67.2.319.

Chang, C.-H., Chang, Y.-C., Cheng, H., & Tzang, R.-F. (2020). Treatment efficacy of internet gaming disorder with attention deficit hyperactivity disorder and emotional dysregulation. *International Journal of Neuropsychopharmacology*, *23*(6), 349–355. https://10.1093/ijnp/pyaa010.

Conners, C. K. (2014). *Conners continuous performance test 3rd edition (Conners CPT 3) & connors continuous auditory test of attention (Conners CATA): Technical manual*. Toronto, ON: Multi-Health Systems.

Corr, P. J. (2004). Reinforcement sensitivity theory and personality. *Neuroscience and Biobehavioral Reviews*, *28*(3), 317–332. https://doi.org/10.1016/j.neubiorev.2004.01.005.

Dickman, S. J. (1990). Functional and dysfunctional impulsivity: Personality and cognitive correlates. *Journal of Personality and Social Psychology*, *58*(1), 95–102. https://doi.org/10.1037/0022-3514.58.1.95.

Dong, G., & Potenza, M. N. (2014). A cognitive-behavioral model of internet gaming disorder: Theoretical underpinnings and clinical implications. *Journal of Psychiatric Research*, *58*, 7–11. https://doi.org/10.1016/j.jpsychires.2014.07.005.

Dong, H., Zheng, H., Wang, M., Ye, S., & Dong, G. H. (2022). The unbalanced behavioral activation and inhibition system sensitivity in internet gaming disorder: Evidence from resting-state Granger causal connectivity analysis. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *119*, 110582. https://doi.org/10.1016/j.pnpbp.2022.110582.

Dullur, P., Krishnan, V., & Diaz, A. M. (2021). A systematic review on the intersection of attention-deficit hyperactivity disorder and gaming disorder. *Journal of Psychiatric Research*, *133*, 212–222. https://doi.org/10.1016/j.jpsychires.2020.12.026.

Gentile, D. A., Choo, H., Liau, A., Sim, T., Li, D., Fung, D., & Khoo, A. (2011). Pathological video game use among youths: A two-year longitudinal study. *Pediatrics*, *127*(2), e319–e329. https://doi:10.1542/peds.2010-1353.

González-Bueso, V., Santamaría, J. J., Fernández, D., Merino, L., Montero, E., & Ribas, J. (2018). Association between internet gaming disorder or pathological video-game use and comorbid psychopathology: A comprehensive review. *International Journal of Environmental Research and Public Health*, *15*(4), 668. https://doi.org/10.3390/ijerph15040668.

González-Bueso, V., Santamaría, J. J., Oliveras, I., Fernández, D., Montero, E., Baño, M., … Ribas, J. (2020). Internet gaming disorder clustering based on personality traits in adolescents, and its relation with comorbid psychological symptoms. *International Journal of Environmental Research and Public Health*, *17*(5), 1516. https://doi.org/10.3390/ijerph17051516.

Granero, R., Fernández-Aranda, F., Castro-Calvo, J., Billieux, J., Valero-Solís, S., Mora-Maltas, B., … Jiménez-Murcia, S. (2021). Subtyping treatment-seeking gaming disorder patients. *Addictive Behaviors*, *123*, 107086. https://doi.org/10.1016/j.addbeh.2021.107086.

Grassi, G., Moradei, C., & Cecchelli, C. (2024). Prevalence and clinical phenotypes of adult patients with attention deficit hyperactivity disorder and comorbid behavioral addictions. *Journal of Behavioral Addictions*, *13*(2), 473–481. https://doi.org/10.1556/2006.2024.00020.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*(2), 348–362. https://doi.org/10.1037/0022-3514.85.2.348.

Han, D. H., Lee, Y. S., Na, C., Ahn, J. Y., Chung, U. S., Daniels, M. A., … Renshaw, P. F. (2009). The effect of methylphenidate on Internet video game play in children with attention-deficit/hyperactivity disorder. *Comprehensive Psychiatry*, *50*(3), 251–256. https://doi:10.1016/j.comppsych.2008.08.011.

Higuchi, S., Nakayama, H., Matsuzaki, T., Mihara, S., & Kitayuguchi, T. (2021). Application of the eleventh revision of the International Classification of Diseases gaming disorder criteria to treatment-seeking patients: Comparison with the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders Internet gaming disorder criteria. *Journal of Behavioral Addictions*, *10*(1), 149–158. https://doi.org/10.1556/2006.2020.00099. 33475527.

Hutchins, N., Allen, A., Curran, M., & Kannis-Dymand, L. (2021). Social anxiety and online social interaction. *Australian Psychologist*, *56*(2), 142–153. https://doi.org/10.1080/00050067.2021.1890977.

Kewitz, S., Leo, K., Rehbein, F., & Lindenberg, K. (2023). Assessment of hazardous gaming in children and its dissimilarities and overlaps with internet gaming disorder. *Frontiers in Psychiatry*, *14*, 1226799. https://doi:10.3389/fpsyt.2023.1226799.

Király, O., Billieux, J., King, D. L., Urbán, R., Koncz, P., Polgár, E., & Demetrovics, Z. (2022). A comprehensive model to understand and assess the motivational background of video game use: The Gaming Motivation Inventory (GMI). *Journal of Behavioral Addictions*, *11*(3), 796–819. https://doi.org/10.1556/2006.2022.00048.

Ko, C. H., Hsieh, T. J., Chen, C. Y., Yen, C. F., Chen, C. S., Yen, J. Y. , … Liu, G. C. (2014). Altered brain activation during response inhibition and error processing in subjects with Internet gaming disorder: A functional magnetic imaging study. *European Archives of Psychiatry and Clinical Neuroscience*, *264*(8), 661–672. https://doi.org/10.1007/s00406-013-0483-3.

Ko, C. H., Király, O., Demetrovics, Z., Chang, Y. M., & Yen, J. Y. (2020). Identifying individuals in need of help for their uncontrolled gaming: A narrative review of concerns and comments regarding gaming disorder diagnostic criteria. *Journal of Behavioral Addictions*, *9*(3), 572–588. https://doi.org/10.1556/2006.2020.00058.

Ko, C., Király, O., Demetrovics, Z., Griffiths, M. D., Kato, T. A., Tateno, M., & Yen, J. (2023). Heterogeneity of gaming disorder: A clinically-based typology for developing personalized interventions. *Journal of Behavioral Addictions*, *12*(4), 855–861. https://doi.org/10.1556/2006.2023.00059.

Ko, C. H., Lin, H. C., Lin, P. C., & Yen, J. Y. (2020). Validity, functional impairment and complications related to internet gaming disorder in the DSM-5 and gaming disorder in the ICD-11. *Australian and New Zealand Journal of Psychiatry*, *54*(7), 707–718. https://doi.org/10.1177/0004867419881499.

Ko, C. H., Liu, T. L., Wu, H. C., Yeh, Y. C., Tsai, W. X., & Yen, J. Y. (2021). Psychiatric comorbidities and emotional intelligence in internet gaming disorder: Attention deficit hyperactivity

disorder, major depressive disorder, generalized anxiety disorder, and social anxiety disorder. *Psychiatry and Clinical Neurosciences*, *75*(11), 352–354. https://doi.org/10.1111/pcn.13295.

Kökönyei, G., Kocsel, N., Király, O., Griffiths, M. D., Galambos, A., Magi, A., … Demetrovics, Z. (2019). The role of cognitive emotion regulation strategies in problem gaming among adolescents: A nationally representative survey study. *Frontiers in Psychiatry*, *10*, 273. https://doi.org/10.3389/fpsyt.2019.00273.

Koncz, P., Demetrovics, Z., Takács, Z. K., Griffiths, M. D., Tamás, N., & Király, O. (2023). The emerging evidence on the association between symptoms of ADHD and gaming disorder: A systematic review and meta-analysis. *Clinical Psychology Review*, *106*, 102343. https://doi.org/10.1016/j.cpr.2023.102343.

Koncz, P., Demetrovics, Z., Urbán, R., Griffiths, M. D., & Király, O. (2024). Gender-specific motivational pathways in ADHD-related inattention and gaming disorder symptoms. *Addictive Behaviors*, *158*, 108120. https://doi:10.1016/j.addbeh.2024.108120.

Kuss, D. J., Pontes, H. M., & Griffiths, M. D. (2018). Neurobiological correlates in internet gaming disorder: A systematic literature review. *Frontiers in Psychiatry*, *9*, 166. https://doi.org/10.3389/fpsyt.2018.00166.

Lee, J., Bae, S., Kim, B. N., & Han, D. H. (2021). Impact of attention-deficit/hyperactivity disorder comorbidity on longitudinal course in internet gaming disorder: A 3-year clinical cohort study. *Journal of Child Psychology and Psychiatry*, *62*(9), 1110–1119. https://doi.org/10.1111/jcpp.13380.

Lin, P. Y., Lin, H. C., Lin, P. C., Yen, J. Y., & Ko, C. H. (2020). The association between emotional regulation and internet gaming disorder. *Psychiatry Research*, *289*, 113060. https://doi.org/10.1016/j.psychres.2020.113060.

Lin, P. C., Yen, J. Y., Lin, H. C., Chou, W. P., Liu, T. L., & Ko, C. H. (2021). Coping, resilience, and perceived stress in individuals with internet gaming disorder in Taiwan. *International Journal of Environmental Research and Public Health*, *18*(4), 1771. https://doi.org/10.3390/ijerph18041771.

Martín-Fernández, M., Matalí, J. L., García-Sánchez, S., Pardo, M., Lleras, M., & Castellano-Tejedor, C. (2016). Adolescents with internet gaming disorder (IGD): Profiles and treatment response. *Adicciones*, *29*(2), 125–133. https://doi.org/10.20882/adicciones.890.

Melodia, F., Canale, N., & Griffiths, M. D. (2022). The role of avoidance coping and escape motives in problematic online gaming: A systematic literature review. *International Journal of Mental Health and Addiction*, *20*, 996–1022. https://doi.org/10.1007/s11469-020-00422-w.

Muller, K. W., Dreier, M., & Wolfling, K. (2023). Personality traits and their role as risk modifiers in gaming disorder and internet use disorders. *Current Opinion in Psychiatry*, *36*(1), 75–79. https://doi:10.1097/YCO.0000000000000827.

Pearce, N. (2016). Analysis of matched case-control studies. *British Medical Journal*, *25*(2), 352–i969. https://doi:10.1136/bmj.i969.

Poznyak, V., Reed, G. M., & Medina-Mora, M. E. (2018). Aligning the ICD-11 classification of disorders due to substance use with global service needs. *Epidemiology and Psychiatric Sciences*, *27*(3), 212–218. https://doi.org/10.1017/S2045796017000622.

Ribes-Guardiola, P., Poy, R., Segarra, P., Branchadell, V., & Moltó, J. (2020). Response perseveration and the triarchic model of psychopathy in an undergraduate sample. *Personality Disorders: Theory, Research, and Treatment*, *11*(1), 54–62. https://doi.org/10.1037/per0000371.

Rizzutti, S., Schuch, V., Augusto, B. M., Coimbra, C. C., Pereira, J. P., & Bueno, O. F. (2015). Neuropsychological profiles correlated with clinical and behavioral impairments in a sample of Brazilian children with attention-deficit hyperactivity disorder. *Frontiers in Psychiatry*, *6*, 163. https://doi:10.3389/fpsyt.2015.00163.

Ropovik, I., Martončik, M., Babinčák, P., Baník, G., Vargová, L., & Adamkovič, M. (2023). Risk and protective factors for (internet) gaming disorder: A meta-analysis of pre-COVID studies. *Journal of Behavioral Addictions*, *139*, 107590. https://doi.org/10.1016/j.addbeh.2022.107590.

Şalvarlı, Ş. İ., & Griffiths, M. D. (2022). The association between internet gaming disorder and impulsivity: A systematic review of literature. *International Journal of Mental Health and Addiction*, *20*(1), 92–118. https://doi.org/10.1007/s11469-019-00126-w.

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., … Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry*, *59*(Suppl 20), 22–33. 9881538.

Teng, Z., Pontes, H. M., Nie, Q., Griffiths, M. D., & Guo, C. (2021). Depression and anxiety symptoms associated with internet gaming disorder before and during the COVID-19 pandemic: A longitudinal study. *Journal of Behavioral Addictions*, *10*(1), 169–180. https://doi.org/10.1556/2006.2021.00016.

Torres-Rodríguez, A., Griffiths, M. D., Carbonell, X., & Oberst, U. (2018). Internet gaming disorder in adolescence: Psychological characteristics of a clinical sample. *Journal of Behavioral Addictions*, *7*(3), 707–718. https://doi.org/10.1556/2006.7.2018.75.

Wang, C.-Y., Wu, Y.-C., Su, C.-H., Lin, P.-C., Ko, C.-H., & Yen, J.-Y. (2017). Association between internet gaming disorder and generalized anxiety disorder. *Journal of Behavioral Addictions*, *6*(4), 564–571. https://doi.org/10.1556/2006.6.2017.088.

Wang, L., Yang, G., Zheng, Y., Li, Z., Qi, Y., Li, Q., & Liu, X. (2021). Enhanced neural responses in specific phases of reward processing in individuals with Internet gaming disorder. *Journal of Behavioral Addictions*, *10*(1), 99–111. https://doi.org/10.1556/2006.2021.00003.

Wang, J., Yin, X., Wang, H., King, D. L., & Rost, D. H. (2024). The longitudinal associations between internet addiction and ADHD symptoms among adolescents. *Journal of Behavioral Addictions*, *13*(1), 191–204. https://doi.org/10.1556/2006.2023.00080.

Weinstein, A., & Lejoyeux, M. (2020). Neurobiological mechanisms underlying internet gaming disorder. *Dialogues in Clinical Neuroscience*, *22*(2), 113–126. https://doi.org/10.31887/DCNS.2020.22.2/aweinstein.

Werling, A. M., Kuzhippallil, S., Emery, S., Walitza, S., & Drechsler, R. (2022). Problematic use of digital media in children and adolescents with a diagnosis of attention-deficit/hyperactivity disorder compared to controls. A meta-analysis. *Journal of Behavioral Addictions*, *11*(2), 305–325. https://doi.org/10.1556/2006.2022.00007.

World Health Organization (2019). *International classification of diseases (11th revision)*. Retrieved 7 March 2024, from https://icd.who.int/en.

Xiang, H., Tian, X., Zhou, Y., Chen, J., Potenza, M. N., & Zhang, Q. (2020). The relationship between behavioral inhibition and behavioral activation systems, impulsiveness, and internet gaming disorder among students of different ages. *Frontiers in Psychiatry*, *11*, 560142. https://doi.org/10.3389/fpsyt.2020.560142.

Yen, J.-Y., Chou, W.-P., Liao, H.-Y., & Ko, C.-H. (2023). Comparing the approaches and validity of ICD-11 criteria for gaming disorder and DSM-5 criteria for internet gaming disorder. *Current Addiction Reports*, *10*(1), 60–68. https://doi.org/10.1007/s40429-022-00459-y.

Yen, J. Y., Higuchi, S., Lin, P. Y., Lin, P. C., Chou, W. P., & Ko, C. H. (2022a). Functional impairment, insight, and comparison between criteria for gaming disorder in the International Classification of Diseases, 11 edition and internet gaming disorder in diagnostic and statistical manual of mental disorders, fifth edition. *Journal of Behavioral Addictions*, *11*(4), 1012–1023. https://doi.org/10.1556/2006.2022.00079.

Yen, J. Y., Lin, P. C., Lin, H. C., Lin, P. Y., Chou, W. P., & Ko, C. H. (2022b). Association of internet gaming disorder with catechol-o-methyltransferase: Role of impulsivity and fun-seeking. *Kaohsiung Journal of Medical Sciences*, *38*(1), 70–76. https://doi.org/10.1002/kjm2.12454.

Yen, J. Y., Lin, P. C., Wu, H. C., & Ko, C. H. (2022c). The withdrawal-related affective, gaming urge, and anhedonia symptoms of internet gaming disorder during abstinence. *Journal of Behavioral Addictions*, *11*(2), 481–491. https://doi.org/10.1556/2006.2022.00008.

Yen, J. Y., Liu, T. L., Wang, P. W., Chen, C. S., Yen, C. F., & Ko, C. H. (2017). Association between internet gaming disorder and adult attention deficit and hyperactivity disorder and their correlates: Impulsivity and hostility. *Addictive Behaviors*, *64*, 308–313. https://doi.org/10.1016/j.addbeh.2016.04.024.

Yen, J. Y., Yeh, Y. C., Wang, P. W., Liu, T. L., Chen, Y. Y., & Ko, C. H. (2017). Emotional regulation in young adults with internet gaming disorder. *International Journal of Environmental Research and Public Health*, *15*(1), 30. https://doi.org/10.3390/ijerph15010030.

Zhang, P., Pan, Y., Zha, R., Song, H., Yuan, C., Zhao, Q., … Zhang, X. (2023). Impulsivity-related right superior frontal gyrus as a biomarker of internet gaming disorder. *General Psychiatry*, *36*(4), e100985. https://doi.org/10.1136/gpsych-2022-100985.

Zhou, W. R., Wang, M., Dong, H. H., Zhang, Z., Du, X., Potenza, M. N., & Dong, G. H. (2021). Imbalanced sensitivities to primary and secondary rewards in internet gaming disorder. *Journal of Behavioral Addictions*, *10*(4), 990–1004. https://doi.org/10.1556/2006.2021.00072.

Appendix
Advertisements used to recruit participants

Project Title: Preparing the brain for recovery: Neurofeedback training in gaming disorder comorbidity with adult ADHD

We are researchers at Kaohsiung Medical University, and this study is a project on 'Gaming Disorder'. We are inviting individuals to participate in one of two groups:
'Gaming Disorder (GD) Group' and 'Healthy Adult Group.
If you meet the conditions of one of the groups, you are welcome to contact us.

Those in the 'GD Group' need to meet the following conditions:

1. Be an online gamer aged between 20 and 40 years.
2. Have an educational background of high school or above.
3. Be an online gamer playing online games for at least five years.
4. Play online games for more than 4 h a day, more than 8 h on Saturdays and Sundays, or more than 40 h per week.
5. Consider online gaming is the main focus of life, affecting relationships, health, education and/or occupation.
6. Cannot bear not gaming online for three days or more.
7. Have no severe physical problems (such as asthma or heart disease).
8. Have no brain injury or severe central nervous system disease.
9. Is currently not taking any psychotropic drugs (such as sleeping pills).
10. Have never used illegal drugs and does not drink alcohol regularly.

Those in the "Healthy Adult Group" need to meet the following conditions:

1. Be aged between 20 and 40 years.
2. Have an educational background of high school or above.
3. It is enough to meet one of (1) or (2)
    1. You often play online games and think they have no significant negative impact on your life or health as a result of online gaming.
    2. You do not play online or rarely play online games, and you think that surfing the internet or playing games has no significant negative impact on your life or health.
4. Have no severe physical problems (such as asthma, heart disease).
5. Have no brain injury or severe central nervous system disease.
6. Is currently not taking any psychotropic drugs (such as sleeping pills).
7. Have never used illegal drugs and does not drink alcohol regularly.