The emerging evidence on the association between symptoms of ADHD and gaming disorder

The emerging evidence on the association between symptoms of ADHD and gaming disorder: A systematic review and meta-analysis

Abstract

The co-existence of gaming disorder (GD) with other mental health problems has been widely reported. Despite the growing research interest in the comorbidity of GD with attention-deficit/hyperactivity disorder (ADHD), to date, no quantitative synthesis has been performed. The present study comprised a systematic literature search using *Scopus, Science Direct, Web of Science,* and *PubMed* databases. Three types of studies were included in the analyses: studies reporting correlation coefficients, means and standard deviations for comparison of GD severity between ADHD/non-ADHD individuals, and comparison of ADHD severity between GD/non-GD individuals. The results indicated a moderate relationship between GD and ADHD symptom severity when both subdomains of ADHD were combined (r=.296), and also when only inattention (r=.306) or hyperactivity (r=.266) symptoms were analyzed, which was also confirmed in a structural equation model meta-analysis. Studies showed a large average difference comparing the GD symptom severity of ADHD and non-ADHD individuals (g=.693), or ADHD symptom severity of GD and non-GD individuals (g=.854). Studies including higher proportion of males, measurement of problematic internet use in predominantly video game user samples instead of measuring purely GD, and studies being more recently published resulted in higher estimates in some cases. The present review shows that it is an emerging field showing significant results in cross-sectional correlational studies, however, further research should apply more rigorous methodology to investigate the relationship further: longitudinal studies and professional (clinical) ratings/diagnosis are suggested. These preliminary results suggest that screening and treatment for ADHD among gaming disordered patients is necessary, while individuals with ADHD should be made aware concerning their higher susceptibility for gaming disorder.

Keywords: attention-deficit/hyperactivity disorder, ADHD, gaming disorder, problematic gaming, comorbidity, meta-analysis

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterized by *"a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development"* (American Psychiatric Association, 2013, p. 59-66). Three types of diagnosis are used to cover the variation of symptom occurrence: (i) combined presentation (when both symptoms co-

occur), (ii) predominantly inattentive presentation (when only the criterion for inattentive symptoms is fulfilled), and (iii) predominantly hyperactive/impulsive presentation (when only the criterion for hyperactive/impulsive symptoms is fulfilled). ADHD is primarily prevalent among the child/adolescent population, and the overall pooled prevalence in this age group has been reported to be 7.2% (Thomas et al., 2015). While symptoms usually disappear with aging, approximately 2.5% of the adult population still experiences them (Simon et al., 2009).

The higher prevalence of ADHD among those dependent on psychoactive substances is well-known. Approximately quarter of individuals with substance use disorder have comorbid ADHD (van Emmerik-van Oortmerssen et al. 2014)), which poses an additional challenge in terms of treatment. This widely established comorbidity is not limited to substance use-related disorders, a higher co-occurrence of ADHD has also been reported among individuals with non-substance use related addictive disorders such as gambling disorder, gaming disorder, and other problematic behaviors such as binge-eating, problematic internet use and compulsive sexual behaviors (Dullur et al., 2020; Karaca et al., 2017; Savard et al., 2021). Disorders due to addictive behaviors or behavioral addictions is a relatively new area with a strong research interest and a continuously growing number of studies (Billieux et al., 2015) due to the large number of individuals affected globally (e.g., Alimoradi et al., 2022). Individuals suffering from behavioral addictions endure severe distress and functional impairment due to specific rewarding behaviors (e.g., playing video games), similar to what individuals with substance use disorders experience (Billieux, et al., 2017). The clinical relevance of these conditions is also demonstrated by the World Health Organization's (WHO) decision to create a new category in the most recent version of the International Classification of Diseases (ICD-11) called "Disorders due to addictive behaviours" and include gaming disorder, gambling disorder, as well as other specified and unspecified disorders due to addictive behaviors in this category (World Health Organization, 2019).

Possible negative consequences of excessive video gaming have long been acknowledged both among researchers and in the clinical field. As a consequence, in 2013, Internet Gaming Disorder (IGD) was included in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) in Section III ('Emerging Measures and Models') as a non-substance-related disorder with a recommendation for further research (American Psychiatric Association, 2013). However, this led to an intense debate between scholars. The most important concerns regarding the inclusion were the following: research underlying the decision was of low quality; the operationalization leaned too much on substance use and gambling criteria; there was a huge variation in symptomatology and assessment of problematic gaming; and making GD a formal diagnosis would cause stigma to the millions of children who play video games in a healthy manner (Aarseth et al., 2017; Ko et al., 2020). Furthermore, some of the IGD criteria (e.g., preoccupation, tolerance, withdrawal) were also heavily criticized as not being suitable to differentiate individuals with GD from gaming enthusiasts (Griffiths, et al., 2015; Király et al., 2015). After thoroughly discussing these concerns, the WHO decided that including GD in the ICD-11 as an official diagnosis had more advantages than disadvantages. Moreover, to address the critiques of specific criteria, the ICD-11 diagnosis only comprises those criteria, which have wide support, especially among

professionals from the clinical field (Castro-Calvo, et al., 2021). Nevertheless, the inclusion was highly criticized by the gaming industry and some researchers, majority of whom were working in the field of media psychology and gaming studies (Ferguson & Colwell, 2020; Galanis et al., 2021).

According to the WHO, GD is a persistent and recurrent pattern of gaming behavior, characterized by loss of control over video game use and neglect of other important areas of life (such as relationships, occupation and/or education), which persist despite the emergence of several negative consequences that clinically impair day-to-day activities (World Health Organization, 2019). A meta-analysis examining studies between 2009 and 2019 found that the worldwide prevalence of gaming disorder was 1.96% in samples with more strict sampling criteria (stratified random sampling) and occurring more frequently among male and adolescent populations (Stevens et al., 2020). Numerous studies have reported associations between GD and other psychopathologies. The most frequently reported comorbidities are anxiety, depression, ADHD, social phobia, obsessive-compulsive symptoms (González-Bueso et al., 2018), and autism spectrum disorder (Murray et al., 2021).

A systematic review of Dullur et al. (2020) showed that the problematic use of video games (and in the more extreme cases, gaming disorder) is associated with ADHD. Recent findings not included in the review by Dullur et al. also reported an association between GD and ADHD (Cabelguen et al., 2021). This is also the case in longitudinal designs, where the association between preceding ADHD symptoms and subsequent GD severity has been shown to be mediated by a lower level of self-control and a higher level of aggression (Jeong et al., 2020).

Research aims

Considering the clinical relevance and frequent co-occurrence of ADHD and GD, the present study had three goals: (i) to test the association between the symptoms of two disorders; (ii) to assess the quality of studies examining the comorbidity of the two disorders; and (iii) to estimate the effect of potential moderators in the association between the two disorders, such as age, gender, culture, methodological characteristics (assessment tool and informant), and overall study quality.

Methods

Systematic search

A systematic literature search was carried out using four different scientific databases: *Scopus, Science Direct, Web of Science* and *PubMed* with the following keywords: "ADHD" AND ("game" OR "gaming" OR "videogame") AND ("addiction" OR "problematic" OR "pathological" OR "disorder" OR "compulsive" OR "dependent" OR "excessive") NOT "gambling". Searches were carried out in three phases, and the final search was on June, 2022, resulting in 839 hits in total . After the deletion of duplicates, 606 papers remained. All findings were exported to *EndNote* (6.0.1 version) software.

Eligibility screening, identification of additional studies

All of the titles and abstracts of the papers were scanned for eligibility by two doctoral students. Disagreements were resolved through discussion. Full texts were scanned to exclude studies (i) that did not assess gaming disorder/problematic internet use in relation to ADHD, but similar constructs (such as screen time), (ii) where problematic internet use was assessed, but the rate of video game use was not reported or less than 50% of the study sample reported playing video games, or (iii) that reported on data from the same database which was already identified in another paper in the present meta-analysis. A total of 95 full-text papers were screened for appropriate data for the meta-analysis. A total of 47 studies were excluded where necessary data were not reported in the paper, and the authors of those studies did not respond to the request through e-mail to provide the missing data. Study authors who were contacted were also asked to share any research related to the association between gaming disorder and ADHD symptoms that had not been published. However, no additional studies were identified through this request. The present authors participated in two additional data collections in Hungary, which provided appropriate, but as yet unpublished data for the association in question. The first study was the Budapest Longitudinal Study (BLS), in which data were collected from a representative sample of fifth grade students. The other was a convenience sample of video game users, which were used to the develop the Gaming Motivation Inventory, a comprehensive tool that assesses motives for video game use (Király et al., 2022). Following this process, 48 studies remained for meta-analysis (see Figure 1). This process was executed following PRISMA guidelines (Moher et al., 2009). All included studies can be found in the Supplementary File (S1).

~ Figure 1 ~

Inclusion and exclusion criteria

The following eligibility criteria were used: empirical studies that reported results of a quantitative analysis concerning the association between GD and ADHD, either cross-sectionally or longitudinally, including a correlation coefficient or a group difference (e.g., ADHD/non-ADHD on symptoms of GD or GD/non-GD on symptoms of ADHD) reported), being published in the English language, and being published in a peer-reviewed journal. There was no restriction on publication date. Studies were excluded, where the purpose of internet use was not reported or lower than 50% of the sample reported gaming.

Coding process and type of data

Coders were undergraduate and graduate students. All coders were trained by the first author. Coding was done in pairs including a graduate and a PhD student, or two BA students under the supervision of the first author. In case of a disagreement between two coders, the first and the second authors were included to resolve the disagreement through discussion.

Three types of outcome data were identified in the primary studies: correlation coefficients (between two numerical variables); the means and standard deviations for symptoms of gaming

disorder or problematic internet use in case of a comparison between a sample with and without ADHD; and the means and standard deviations for ADHD symptom severity in case of a comparison between participants with and without gaming disorder or problematic internet use. These were analyzed in three separate meta-analyses. In the first case, the correlation coefficients were coded as an effect size, while in the latter two analyses, Hedges' g was calculated for the standardized mean difference between the groups. In case of correlations, the type of correlation (Pearson or Spearman) was also coded in order to investigate whether they could be merged in the same analysis. Data related to ADHD symptom severity was coded for the two subdomains of ADHD separately (inattention and hyperactivity/impulsivity) if the data were available.

In case of longitudinal studies, cross-sectional data from the first data collection phase was coded with one exception. The one exception was the study by Marmet et al. (2018), where the use of the data from the third wave was recommended by the authors, as at that time point no modifications were applied to the assessment tool (i.e., Gaming Addiction Scale), and probably resulting in more reliable estimates.

The following moderator variables were coded: sample type (clinical/non-clinical), mean age of the sample, gender distribution in the sample, country data were collected in, year of data collection, ADHD assessment tool and the informant (self-report/parent report/teacher report/professional rating), GD/IA assessment tool and the informant (self-report/parent report/teacher report/professional rating), and the type of addiction (only gaming-related problems or problems partly related to gaming and partly to any other internet-based activities). Samples were categorized as clinical, when the participants were recruited from mental healthcare institutions and where they received official diagnosis, while samples were categorized as non-clinical when they were recruited from other places than mental healthcare institutions (e.g., schools, gaming-related sites and forums). For the year of data collection, if it was not reported in the paper, the value was imputed by the publication year -2 formula (for a similar procedure, see Protzko, 2020). Where data were collected over two years, the mean of the publication years was coded. To unify the different scale names used in the studies, five review studies were used (i.e., Collett et al., 2003; Taylor et al., 2011; Laconi et al., 2014; King et al., 2013, 2020). Inter-rater reliability was calculated separately for effect size data (sample sizes, correlation coefficients, means, and standard deviations) and for moderators (mean age, gender distribution, year of data collection, etc.). The inter-rater reliability percentages were acceptable for both the outcome measures (97%) and the moderators (95%).

Contact with the study authors

Study authors were contacted through e-mail to collect information not reported in their studies, such as data to calculate an effect size and values for moderator variables. Additionally, authors with multiple papers were asked questions regarding possible overlap of the samples in these studies. Non-independent samples were removed from the final database in order to make sure that participants were only included once in the analyses.

Quality assessment

For the assessment of the methodological quality of the studies included in the present meta-analysis, the protocol of Murray et al. (2021) was followed, and studies were rated on five criteria: (i) the relevancy and importance of research question; (ii) the evidence and appropriateness of study design; (iii) the possibility of sampling bias; (iv) how well-defined and robust the ADHD assessment was; and (v) how well-defined and robust GD assessment was. All criteria were rated on a 0-2 scale by graduate students in pairs. If any disagreement occurred, it was resolved by discussion with the inclusion of one of the authors. Overall study quality score ranged between 0-10. Studies were rated as (i) high quality with a score of 8 or more; (ii) medium quality with a score of 3 to 7.5; and low quality with a score below 3.

Statistical analysis

Data were analyzed using the *Comprehensive Meta-Analysis Version 3.0* software (Borenstein, Hedges, Higgins, & Rothstein, 2009). The random-effects model was used in all analyses. For correlational data, results were inspected using both the correlation coefficient and Fisher's z-values as the effect size. Results were very similar regarding these two values so results of correlation coefficients are reported. For data regarding group differences, the means and standard deviations were used to calculate the standardized mean difference Hedges' *g* as the effect size. Additional studies not suitable for data synthesis (because of the low number of such studies with decent heterogeneity in the reported statistical indicators) were included with their results being reported qualitatively. These studies utilized ratings made by professionals (clinicians) for the diagnosis of both disorders reporting the rates of having an ADHD diagnosis in groups with and without GD. Furthermore, a qualitative description of the longitudinal studies was also included.

Outliers exceeding a standardized residual of +/-3.29 were removed from the analyses. The software weights the studies according to the inverse of the standard error so that studies with larger samples have more weight in the average effect. The possibility of publication bias was tested in all analyses using the funnel plot method (Egger et al., 1997). In case asymmetry was identified, Duval and Tweedie's (2000) trim and fill method was utilized to adjust the average effect size. Additionally, Rosenthal's fail-safe N method (Rosenthal, 1979) was used to calculate the number of studies required to turn the results non-significant. As a rule of thumb, an estimate exceeding 5k+10 can be interpreted as reflecting a robust average effect. Heterogeneity of the average effects was assessed using the Q-statistic and I^2 (Borenstein et al., 2009).

In cases of notable heterogeneity, meta-regressions were run to test the effect of the sample's mean age, gender distribution, and the year of data collection. Subgroup analyses were carried out if more than two studies reported sufficient data to perform subgroup analysis between at least two subgroups for the following variables: sample type, country of data collection, ADHD assessment tool and informant (for ADHD), GD/IA assessment tool and informant (for GD/IA). For the interpretation of Cohen's *d* and Pearson Product Moment *r* values, the guidelines of Cohen (1988) were used.

The correlation between GD and the two subdomains of ADHD was also explored using a structural equation model (SEM) meta-analysis (Cheung & Chan, 2009). This approach allowed for the simultaneous analysis of GD and both ADHD subdomains within a single model, considering their correlation. By combining the outcomes in this way, the analysis benefits from increased statistical power, enabling more precise estimates and potentially more reliable results (Harrer et al., 2021).

Results

Descriptive statistics

From the 39 studies reporting correlational data, 43 independent samples were identified (Table 1). More specifically, 32 effect sizes were found for the correlation between GD and inattention symptoms and 31 effect sizes were found for the correlation between GD and hyperactivity/inattention symptoms. Seven studies comprising seven effect sizes reported on group comparisons between ADHD and non-ADHD individuals regarding GD symptom severity (Table 2). Finally, six studies reporting seven effect sizes were found comparing groups of GD and non-GD responders regarding ADHD symptom severity (Table 3).

~ Table 1 ~

~ Table 2 ~

~ Table 3 ~

Preliminary subgroup analysis for studies with parametric and non-parametric correlation

A preliminary analysis tested whether the effect sizes based on non-parametric correlation analyses (i.e., Spearman's correlation coefficients) had a different average effect size compared to the effect sizes using parametric correlation results (i.e., Pearson's correlation coefficients) using mixed effect model estimates for the association between GD and combined ADHD, inattention, and hyperactivity/impulsivity scores. The average effect size was similar in studies reporting non-parametric correlation statistics (r=.308, k=6, SE=0.0334, 95% CI=[.241; .372], p<.001) compared to parametric statistics (r=.294, k=35, SE=0.0171, 95% CI=[.260; .327], p<.001)(Q=0.140, df=1, p=.708) with combined ADHD scores.

Secondly for the analysis including inattention scores, no difference was found between the average effect sizes of studies reporting non-parametric correlation statistics (r=.331, k=4, SE= 0.0569, 95% CI=[.215; .438], p<.001) compared to parametric statistics (r=.302, k=27, SE= 0.0219, 95% CI=[.258; .344], p<.001)(Q=0.222, df=1, p=.637). Similarly, the subgroup analysis did not indicate difference between the average effect sizes of studies reporting non-parametric correlation statistics (r=.297, k=4, SE= 0.0538, 95% CI=[.188; .399], p<.001) compared to parametric statistics (r=.260, k=25, SE=0.0217, 95% CI=[.217; .302], p<.001) (Q=0.408, df=1, p=.523) including hyperactivity/impulsivity scores. Given the analyis found no indication that different correlation coefficients may overestimate or underestimate the

association, no studies were excluded from the analysis where Spearman's correlation was used.

Meta-analysis of studies reporting on correlational analyses

A medium-sized, significant positive association was found between combined ADHD scores and gaming disorder symptom severity: r=.296, k=41, SE= 0.0153, 95% CI=[.266, .326], p<.001 (Figure 2). More specifically, gaming disorder symptom severity also showed moderate-sized significant average correlations with both ADHD inattention scores (r=.306, k=31, SE=0.0202, 95% CI=[.266, .345], p<.001) (Figure 3) and ADHD hyperactivity/impulsivity scores (r=.266, k=29, SE= 0.0202, 95% CI=[.226, .305], p<.001) (Figure 4). In all three average effects, there was significant heterogeneity between the studies (Q=481.003, df=40, p<.001, I^2=92% for the effect sizes with combined ADHD scores; Q=306.437, df=30, p<.001, I^2=90% for the effect sizes with ADHD inattention scores; Q=258.426, df=28, p<.001, I^2=89% for the effect sizes with ADHD hyperactivity/impulsivity scores).

~ Figure 2 ~

~ Figure 3 ~

~ Figure 4 ~

According to the classic fail-safe N method these average effects were robust (i.e., 31,960 non-significant studies would be needed to turn the average effect non-significant in case of combined ADHD symptom severity scores, 13,912 studies in case of ADHD inattention symptom severity scores, and 8016 studies in case of ADHD hyperactivity/impulsivity severity scores). Funnel plots including the combined and the subdomain scores of ADHD showed some slight asymmetry. Duval and Tweedie's Trim and Fill method indicated one trimmed study for studies with combined ADHD scores, where the adjusted average effect remained significant (r=.294, 95% CI=[.264; .324], p<.001)(Figure 5). Regarding ADHD inattention scores, three trimmed studies were identified, where the average effect size, again, remained significant (r=.291, 95% CI=[.251; .330], p<.001) (Figure 6). Finally, in the case of ADHD hyperactivity/impulsivity scores, six trimmed studies were calculated, resulting in a significant adjusted average effect size (r=.2223, 95% CI=[.180; .265], p<.001) (Figure 7).

~ Figure 5 ~

~ Figure 6 ~

~ Figure 7 ~

As a result of the subgroup analysis comparing the effect sizes between the two types of disorders assessed, significantly larger correlation coefficient estimates between GD symptom scores and ADHD inattention subdomain scores were found for studies assessing problematic internet use in predominantly video game user samples compared to studies where purely

gaming disorder severity was assessed (Figure 8). Furthermore, gender ratio positively predicted the correlation coefficient between gaming disorder severity and combined ADHD scores (Figure 9), suggesting that the association is larger for males, but the effect estimate was negligible Neither the remaining subgroup analyses (clinical versus non-clinical samples, country of data collection (Germany, Turkey, USA), GD assessment tools (Internet Addiction Test, Internet Gaming Disorder Scale Short-Form, Problem Videogame Playing Scale) and source (self-report versus parent-report), ADHD assessment tools (ADHD Rating Scale-IV, Adult Self Report Scale 6-item screener version, Adult Self Report Scale 18-item version) and source (self-report or parent-report), nor the other meta-regressions (mean age of the sample, year of data collection, overall study quality) performed on the average correlation coefficients including any ADHD data type (combined, inattention, hyperactivity/impulsivity) resulted in significant results regarding potential moderators (Tables 4-7). Average effect sizes in all categories in the subgroup analyses showed moderately-sized significant positive correlations between GD and ADHD symptoms, irrespective of the characteristics of the sample or the assessment tool used (Table 4-6).

~ Table 4 ~

~ Table 5 ~

~ Table 6 ~

~ Table 7 ~

~ Figure 8 ~

~ Figure 9 ~

SEM meta-analysis

In the first step of the analysis, we examined the data from thirteen studies that provided information on the correlation between Hyperactivity/Impulsivity and Inattention. Combining the data, we found that the weighted mean correlation between these two outcomes was r = 0.35. Subsequently, we calculated the study-level covariances of the two outcomes that we used to fit the model (Cheung & Chan, 2009).

We found that the univariate effect sizes for the relation between symptoms of ADHD and GD were both significantly larger than zero. For Hyperactivity/Impulsivity, the correlation was r = .28 (95%CI [.22, .34] z = 8.37, p < .001). Similarly, for Inattention, the correlation was r = .33 (95%CI [.27, .38] z = 10.91, p < .001). Both effects displayed substantial heterogeneity, exceeding 95%. Moreover, we found a strong positive association between the two effects (r = .90). In other words, individuals who exhibit higher levels of GD are likely to experience both Hyperactivity/Impulsivity and Inattention symptoms of ADHD concurrently.

~ Figure 10 ~

Meta-analysis on studies including group comparison results

In studies where individuals with and without an ADHD diagnosis were compared, a moderate-to-large positive difference was found regarding GD symptom severity: g=.693, k=7, SE=.129, 95% CI=[.440, .945], p<.001 (Figure 11). Similarly, studies comparing individuals with and without gaming disorder also showed a significant, large difference: g=.854, k=7, SE=.226, 95% CI=[.411, 1.296], p<.001 (Figure 12). The analyses indicated significant heterogeneity among the studies (Q=37.010, df=6, p<.001, I^2=84% for GD symptom severity in ADHD/non-ADHD comparison; Q=60.921, df=6, p<.001, I^2=90% for ADHD symptom severity in GD/non-GD comparison).

~ Figure 11 ~

~ Figure 12 ~

The classic fail-safe N method indicated that 321 non-significant results would be necessary to turn the average difference between the ADHD and non-ADHD groups non-significant and 261 for the group comparison between GD and non-GD groups. These results suggest robust effects. The funnel plots showed symmetrical distributions. Duval and Tweedie's Trim and Fill method did not indicate any trimmed studies for either the ADHD/non-ADHD, or for the GD/non-GD comparison. Therefore, no evidence of publication bias was found and the average effects were robust.

Although the number of available studies was quite low, moderator analyses were carried out where appropriate. Only one continuous moderator showed a significant effect in these group comparison meta-analyses. The year of data collection (ranging from 2007 to 2019) positively predicted the size of the difference in gaming disorder symptom severity between ADHD and non-ADHD individuals in the available seven studies (i.e., more recent studies tended to find a larger difference; Figure 13). This was a small association showing 0.05 point of increase in symptom severity of GD with every year. All other meta-regressions showed non-significant results (Table 8).

~ Figure 13 ~

Subgroup analyses could only be performed for the type of addiction measured for the group mean difference estimates of combined ADHD symptom severity between GD and non-GD groups. When pooling effect sizes in studies measuring gaming disorder showed a significant, large difference (g = 0.798, k = 4, SE = 0.156, 95% CI = [0.493, 1.105], p<.001), while studies assessing problematic internet use in predominantly video game user samples showed a large average difference that failed to reach significance (g = 0.879, k = 3, SE = 0.457, 95% CI = [-0.017, 1.775], p=.054)(Q = 0.028, df=1, p=.868).

Subgroup analyses were performed for studies where ADHD and non-ADHD individuals were compared for the person of informant and the sample type of the ADHD group (clinical or non-clinical). Professional ratings showed a significant, moderate-sized effect (g = 0.623, k = 3, SE = 0.173, 95% CI = [0.285, 0.962], p<.001), while pooling self-reported ratings resulted in a

large average difference (g = 0.877, k = 3, SE = 0.173, 95% CI = [0.539, 1.216], p p<.001) of gaming disorder symptoms severity when ADHD and non-ADHD individuals were compared. (Q= 1.081, df=1, p=.299). A similar result was found when attempting to compare the effects found in clinical and non-clinical samples. Studies including clinical samples showed a large average difference (g = 0.795, k = 4, SE = 0.132, 95% CI = [0.537, 1.053], p<.001), while studies applying non-clinical samples found a moderate-sized difference (g = 0.630, k = 3, SE = 0.211, 95% CI = [0.530, 0.968], p=.003)(Q = 0.446, df=1, p=.504).

~ Table 8 ~

In summary, medium-to-large significant, positive differences were found in all subgroup analyses of ADHD/non-ADHD and GD/non-GD group comparison with one exception: no significant difference was found in studies where GD and non-GD groups were compared using measurement for problematic internet use in predominantly video game user samples.

Studies with professional/clinical diagnosis of both ADHD and GD

Two small scale studies found substantially different rates of ADHD among GD patients: 12.5% (Van Rooij, Schoenmakers, Van de Mheen 2017) and 83.3% (Bozkurt et al., 2013), while a large-scale study including 755 GD patients reported the rate of co-existent ADHD in 32.7% of the cases (Han et al., 2018). One case-control study reported rates of ADHD diagnosis among GD patients and an age, gender and education level matched control group, indicating that it is more than 13 times more likely to have a diagnosis of ADHD among individuals with GD (Yen et al., 2017).

Findings of longitudinal studies

We found six studies that reported on longitudinal links between ADHD and GD. The question of a possible longitudinal association between the symptoms of the two disorders was first explored in the study of Ferguson & Ceranoglu (2014). In their study, pre-existing attention problems predicted problematic gaming later after controlling for gender (β=0.19), but the opposite direction was non-significant. Peeters and colleagues (2018) only tested the effect of earlier inattentive symptoms on later GD symptoms, which was found to be significant after controlling for gender. The association between the two problems was stronger for socially vulnerable individuals with low life-satisfaction. Wartberg and colleagues (2018) tested both directions of predictive effect and similar to previous research findings, only previously present ADHD symptoms were predicting subsequent GD symptoms (β=0.14). In contrast, both directions were significant in a large-scale study of Marmet and colleagues (2018), indicating a bidirectional association between the symptoms of the two disorders (probit=0.066 for the prediction of GD symptoms from earlier ADHD symptoms; probit=0.058 for the prediction of ADHD symptoms from earlier GD symptoms). In further analysis, the same association was tested including the two subdomains of ADHD in the same model, finding reciprocal association only in case of inattentive symptoms (probit=0.090 for the prediction of GD symptoms from earlier inattention symptoms; probit=0.044 for the prediction of inattention symptoms from earlier GD symptoms), but not hyperactivity/impulsivity. One additional study

of only ADHD affected individuals indicated that inattentive symptoms, but not hyperactivity symptoms predict GD symptom severity (Schoenmacker, 2020). In contrast to the previous findings, the prospective association between earlier ADHD symptoms and later GD symptoms was not significant in the study of Wichstrøm and colleagues (2019).

Quality assessment

Based on the quality assessment, no low-quality studies were identified, and most of the studies (38 out of 52) were rated as high-quality in general (Table 9-11). Among studies reporting correlation analysis, only the possibility of sampling/selection bias was identified as a common problem (Table 9). In studies including group comparisons between ADHD and non-ADHD individuals, sampling/selection bias and the use of less reliable GD/IA assessment tools were identified, affecting general study quality (Table 10). Ratings of studies including a comparison between GD and non-GD samples were all rated high in all aspects, with no systematic quality issue (Table 11).

~ Table 9 ~

~ Table 10 ~

~ Table 11 ~

Discussion

Data from all available studies focusing on the association between ADHD and GD symptoms were synthesized in the present study to estimate the average size of the relationship, examine the effect of publication bias, and to explore the effect of potential moderators. Based on cross-sectional correlational results, a medium-sized significant positive correlation was found between the two disorders, which was true for the association with both inattention and hyperactivity/impulsivity subdomain scores. A SEM meta-analysis that controlled for the correlation between the two dimensions of ADHD symptoms did not only confirm that both aspects are related to GD symptoms but suggested that individuals who exhibit higher levels of GD are likely to experience both hyperactivity/impulsivity and inattention symptoms of ADHD concurrently. This finding suggests a common underlying mechanism or shared risk factors contributing to the co-occurrence of GD and both subtypes of ADHD. In the meta-analysis of studies applying group comparison, moderate-to-large differences were found in both studies where the GD and non-GD individuals were compared using ADHD symptom severity scores and in studies where ADHD and non-ADHD individuals were compared using GD symptom severity scores. The present study extends the knowledge regarding common GD comorbidities, as previously the co-occurrence of depression and sub-clinical depressive symptoms (Ostinelli et al., 2021) and autism spectrum disorder (Murray et al., 2020) were confirmed using meta-analysis methodology.

The present meta-analysis also provides an overview of the field in regards to research methods. We found that the majority of the studies reported cross-sectional results based on self-report. Interestingly, the single study, which reported a correlation coefficient based on

professional rating (clinicians' rating) for both ADHD and GD found only a weak relationship, which warrants for further studies using professional assessment as opposed to self-report. On the contrary, studies reporting the diagnostic status of participants based on professional rating (clinicians' rating) found considerable rates of ADHD among GD patients. We also unveiled a lack of longitudinal designs and measures based on clinicians' ratings in the field. Accordingly, it should be noted that the present results are not informative regarding causality or even the direction of the effect or temporal precedence. When qualitatively assessing the available six studies regarding longitudinal links, we found contrasting results. Four studies only found a link between pre-existing ADHD symptoms (especially inattention) and later GD symptoms. One study found evidence for a bidirectional relationship, while another failed to find any longitudinal links. Thus, it seems that emerging evidence highlights the potential in investigating the co-occurence of the two disorders, however, future studies with more methodological rigor including longitudinal studies and clinicians' ratings will be needed 1. to confirm this association and 2. to establish temporal precedence and the direction of the association. Finally, future studies might also aim to further investigate the question whether there is a causal relationship between the two or the association is due to common vulnerabilities (e.g., common genetic factors) or confounds (e.g., an overlap in the diagnostic criteria) (Stander et al., 2014).

Even though there is still relatively little data to estimate the effect of potential moderators, the results did not show significant effects of almost any of the moderators, such as age, country, sample type, tool of assessment or informant and only a negligible effect for gender ratio between GD and combined ADHD symptoms association. This might indicate that the association between GD and ADHD is universal, however it should be considered that the moderator analyses might have been underpowered with the relatively small amount of studies that we could include in this meta-analysis. Previous studies have suggested that ADHD and GD are more prevalent among younger populations (Simon et al., 2009, Wilcutt et al., 2012, Stevens et al., 2020). The present study found no proof for the effect of age on the association between the two disorders, and neither for the ADHD sub-domains. Based on these findings, maturation may not lead to a decrease in GD vulnerability among individuals affected by ADHD symptoms. In addition, GD is more prevalent among the male population (Stevens et al., 2020), and ADHD-affected males show higher symptom severity on both subdomains compared to ADHD-affected females (Gershon, 2002), and this factor did moderate the association between the two disorders, indicating stronger association for samples where most of the participants are males, but the related effect estimate (coefficient=0.0018, 95% CI=[.0001; .0035], p<.05) was negligible. Furthermore, correlation coefficients calculated from clinical samples did not result in a different estimate of the association as compared to correlation coefficients from non-clinical samples. The study did not find a larger difference in GD symptoms between ADHD and non-ADHD groups, neither when clinical ADHD groups were compared to non-clinical control groups, nor when non-clinical ADHD groups were compared to non-clinical control groups. Testing the effect of culture was only feasible for the association between combined ADHD scores and GD scores between German and Turkish samples. This comparison did not indicate a significant difference in the association between the two countries. However, when interpreting these results, it should be noted that these non-

significant results might be due to low statistical power and thus should be interpreted with caution.

The operationalization of psychological problems can affect prevalence estimates (Kim et al., 2022). Therefore the effect of assessment tools, informants, and type of addiction were tested. The most frequently used instruments to assess gaming disorder severity were the Internet Addiction Test (Young, 1998), the Internet Gaming Disorder Scale Short-Form (Pontes & Griffiths, 2015), and the Problem Video Game Playing scale (Salguero, Morán, 2002). For assessment of ADHD, the ADHD Rating Scale (DuPaul, 1998), the six-item and 18-item Adult Self-Report Scale (Kessler et al., 2005; Ustun et al., 2017), along with parental reports in case of children. The comparison of specific tools or different informants did not produce different estimates for the association between the two disorders, neither for combined ADHD scores, nor for the subdomain scores of ADHD. This is in line with the findings of another meta-analysis, in which the association between ADHD and the problematic use of the internet (PUI) was not affected by the person of the informant (self- vs. parent-rating) (Werling, Kuzhippallil, Emery, Walitza, & Drechsler, 2022).

Since several tools were used to assess problematic use of the internet, most often among samples of gamers, instead of using gaming disorder instruments, the present study compared the potential effect of the disorder type assessed. A significantly stronger association was found between GD symptoms and inattentive symptoms in studies assessing problematic internet use in predominantly video game user samples compared to studies where purely gaming disorder severity was assessed. These results might indicate that the presence of inattentive symptoms of ADHD is a risk factor for the problematic use of numerous other online activities, such as addictive use of social media (Andreassen et al., 2016), online problematic pornography consumption (Bőthe et al., 2017), and online problem gambling (Theule et al., 2019), rather than online gaming only. These findings are in line with the findings of the aforementioned meta-analysis, where the association between ADHD and PUI was explored (Werling et al., 2022).

Finally, we examined the quality of the primary studies as a moderator in addition to the year of data collection. Study quality did not moderate the association between GD and combined ADHD, inattention or hyperactivity/impulsivity symptom severity. In other words, the association found between GD and ADHD in the present meta-analysis cannot be attributed to the quality of studies. Conflicting results were found for the year of data collection. While correlation estimates and ADHD symptom severity differences in group comparison between GD and non-GD individuals were not associated with the year of data collection, newer studies reported larger differences in GD symptom severity between ADHD and non-ADHD individuals. However, as this association was only found in one analysis, it is unclear whether the association may be strengthening over time. The result might simply be the consequence of a confounding variable such as a change in methodology, a trend in different assessment instruments for instance.

Although the present results cannot establish causality or even the temporal direction of the association, several underlying mechanisms could be involved. A major factor to explain the

association between the two disorders is impulsivity (Yen et al., 2017, Li et al., 2016). One important characteristic of children with ADHD is the preference of immediate over delayed rewards (delay aversion) (Sonuga-Barke, 2002). Regarding excessive gaming, there are a wide range of experimental neurocognitive studies showing on average a moderate difference in response inhibition between GD individuals compared to healthy controls (Argyriou et al., 2017). Lower level of inhibitory control can lead to more hours spent on gaming, but impulsive decision making can also be a consequence of pre-existent GD (Kräplin et al., 2021). Brain imaging studies also found corresponding evidence of alterations in the prefrontal-striatal circuitry, which may be responsible for the comorbidity through enhanced reward craving and deficits in behavioral control (Gao et al., 2021).

Affective functioning may be another important area of consideration. Patients with comorbid ADHD and GD show more internalizing symptoms, especially withdrawal and depression (Berloffa et al., 2022). A study of Chen and colleagues (2021) demonstrated that depression severity and hopelessness mediate the relationship between the symptoms of the two disorders and problematic gaming can lead to progression of disruptive mood dysregulation among ADHD patients (Tzang, Chang, Chang, 2022). Patients suffering from both ADHD and GD are also characterized with higher negative urgency (a tendency to immediately react inadequately, when facing negative emotions) (Cabelguen et al., 2021), leading to higher tendency to escape into video games, as an attempt to cope with negative feelings. In addition to the emotional disturbances and maladaptive responsiveness, technology use can also result in higher level of daytime sleepiness for individuals living with ADHD (Bourchtein et al., 2019), potentially affecting the presentation of both GD and ADHD symptoms.

Social functioning in ADHD affected individuals, presenting in the form of intrusiveness and aggressivity have several consequences, such as unpopularity, peer rejection or lack of reciprocal relationships (Nijmeijer et al., 2008). Social difficulties are a risk factor for GD, as online video games can be used to compensate for needs that are hard or impossible to satisfy in everyday life (Király et al., 2023). In accordance with this, predominantly inattentive type ADHD individuals are often characterized by social anxiety (Koyuncu et al., 2015) and it was demonstrated that social phobia may contribute to a higher risk of developing problematic internet use of ADHD individuals (Demirtas et al., 2021). Purely ADHD sample based studies of Chou and colleagues (Chou et al., 2015; 2017) also support this hypothesis. Both dissatisfaction with family relationships (2015) and social skill deficits (2017) are associated with a heightened risk for problematic internet use. Beyond that, low self-esteem was also found to be predictive for the comorbidity between ADHD and GD (Cabelguen et al., 2021).

Research of Volkow and colleagues (2011) showed that D2/D3 dopamine receptor availability may be responsible for motivation deficits in individuals with ADHD. Boredom proneness is a characteristic associated with symptoms of ADHD (Malkovsky et al., 2012). Therefore, one idea is that ADHD individuals may have a greater need for highly stimulating activities, such as video games (Chou, Chang, Yen 2018) to reach an optimal level of arousal (Paulus et al., 2018 in Dullur, Krishnan, Diaz et al., 2020). The higher tendency of ADHD individuals for immersion into video games may be one factor contributing to greater vulnerability for

problematic use (Jung et al., 2020), which may be a manifestation of ADHD-related hyperfocus (Hupfeld, Abagis, Shah 2018). Findings of decreased gray matter volume and lower activity in patients with both GD and ADHD in the insula supports this idea by showing that lower cognitive control, increased distractibility, and motivational deficits typical in ADHD and habituation to gaming-related and desensitization to conventional stimuli in GD have common neural foundations (Gao et al., 2021).

Limitations

While the present meta-analysis aimed to synthesize evidence from different research designs, mostly cross-sectional studies using self-report measures were available and could be quantitatively synthesized. Only a handful of studies reported on longitudinal associations with conflicting results. Thus, causality or even the direction of effect could not be determined at this point. Thereby, it is possible that ADHD symptoms may cause the emergence of gaming disorder, or it is also possible that gaming (or problematic gaming) may cause ADHD symptoms. Alternatively, a bi-directional association is also possible, as proposed by Marmet and colleagues (2018). Finally, another possible explanation is that a third factor may explain the co-occurrence of the two disorders, such as impaired decision-making or self-regulation, which can be the result of a previously present deficit in the ventromedial prefrontal cortex (Schettler, Thomasius, & Paschke, 2022), or common vulnerabilities such as genetic risks.

The large-scale methodological heterogeneity found between studies led to some difficulties in analysis and interpretation. Most of the studies included in the meta-analysis comprised correlation coefficients because these types of data were reported most often, while some studies, where mostly clinical groups of ADHD or GD individuals were compared to control groups, reported mean differences and standard deviations. Thereby, these types of data were not suitable to be merged into one analysis, which led to lower numbers of studies in all three data analysis types.

Furthermore, as a result of the methodological heterogeneity in categorical data (e.g., use of different assessment tools or the implementation of a scale in modified format), running subgroup analysis was not possible on the studies reporting on group comparisons. It was only feasible in case of some categorical moderators for correlations. Finally, there were relatively few studies resulting in the possibility of low statistical power. This was especially the case for moderator analyses where only a low number of studies could be included. Therefore, non-significant results should be interpreted with caution.

Conclusion

Overall, the study found small-to-large associations between the symptoms of gaming disorder and both attention-deficit/hyperactivity disorder subdomains (inattention and hyperactivity/impulsivity) and combined ADHD symptom severity. A stronger association was found between ADHD inattentive symptoms and GD symptom severity among studies assessing problematic internet use in predominantly video game user samples compared to studies where purely gaming disorder severity was assessed. Similarly, the significant effect of

year of data collection was only found in one analysis: when GD symptom severity was compared between ADHD and non-ADHD individuals. All studies were rated medium-to-high quality as far as cross-sectional studies are concerned. However, the results show that there is a great need for longitudinal studies to establish temporal precedence and the direction of the effect in addition to assessment based on clinicians' ratings or diagnosis.

The use of robust psychometric instruments suitable for cross-culturally comparison is highly recommended, such as the IGDT-10 (Király et al., 2017, 2019) or the IGDS-9SF (Pontes & Griffiths, 2015). Moderator analyses should be run again in the future, when more data are available in the different categories (sample type, country, assessment tool, informant, type of disorder examined). The present results highlight the co-occurence of the two disorders, however, further research with more rigorous methodology are needed to confirm the association and investigate the temporal direction and possible causation. On a practical note, screening of both disorders is recommended in the presence of either.

References

Aarseth, E., Bean, A. M., Boonen, H., Michelle Colder Carras, Coulson, M., Das, D., . . . Van Rooij, A. J. (2017). Scholars' open debate paper on the World Health Organization ICD-11 Gaming Disorder proposal. *Journal of Behavioral Addictions, 6*(3), 267-270. https://doi.org/10.1556/2006.5.2016.088

Alimoradi, Z., Lotfi, A., Lin, C.-Y., Griffiths, M. D., & Pakpour, A. H. (2022). Estimation of behavioral addiction prevalence during COVID-19 pandemic: A systematic review and meta-analysis. *Current Addiction Reports*, *9*, 486–517. https://doi.org/10.1007/s40429-022-00435-6

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Publishing.

Argyriou, E., Davison, C. B., & Lee, T. T. (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

Berloffa, S., Salvati, A., D'acunto, G., Fantozzi, P., Inguaggiato, E., Lenzi, F., ... & Masi, G. (2022). Internet gaming disorder in children and adolescents with attention deficit hyperactivity disorder. *Children*, 9(3), 428. https://doi.org/10.3390/children9030428Billieux, J., King, D. L., Higuchi, S., Achab, S., Bowden-Jones, H., Hao, W., . . . Saunders, J. B. (2017). Functional impairment matters in the screening and diagnosis of gaming disorder: Commentary on: Scholars' open debate paper on the World Health Organization ICD-11 Gaming Disorder proposal (Aarseth et al.). *Journal of Behavioral Addictions*. https://doi.org/10.1556/2006.6.2017.036

Billieux, J., Schimmenti, A., Khazaal, Y., Maurage, P., & Heeren, A. (2015). Are we overpathologizing everyday life? A tenable blueprint for behavioral addiction research. *Journal of Behavioral Addictions*, *4*(3), 119-123. https://doi.org/10.1556/2006.4.2015.009

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2009*). Introduction to meta-analysis*. John Wiley.

Bourchtein, E., Langberg, J. M., Cusick, C. N., Breaux, R. P., Smith, Z. R., & Becker, S. P. (2019). Featured article: Technology use and sleep in adolescents with and without attention-deficit/hyperactivity disorder. *Journal of pediatric psychology*, 44(5), 517-526.

Bőthe, B., Koós, M., Tóth-Király, I., Orosz, G., & Demetrovics, Z. (2019). Investigating the associations of adult ADHD symptoms, hypersexuality, and problematic pornography use among men and women on a largescale, non-clinical sample. *The Journal of Sexual Medicine*, *16*(4), 489-499.

Bozkurt, H., Coskun, M., Ayaydin, H., Adak, I., & Zoroglu, S. S. (2013). Prevalence and patterns of psychiatric disorders in referred adolescents with Internet addiction. *Psychiatry and clinical neurosciences*, 67(5), 352-359.

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.

Castro-Calvo, J., King, D. L., Stein, D. J., Brand, M., Carmi, L., Chamberlain, S. R., . . . Yücel, M. (2021). Expert appraisal of criteria for assessing gaming disorder: An international Delphi study. *Addiction, 116*(9), 2463-2475. https://doi.org/10.1111/add.15411

Chen, C., Dai, S., Shi, L., Shen, Y., & Ou, J. (2021). Associations between attention deficit/hyperactivity disorder and internet gaming disorder symptoms mediated by depressive symptoms and hopelessness among college students. *Neuropsychiatric Disease and Treatment*, *17,* 2775.

Cheung, M. W. L., & Chan, W. (2009). A Two-Stage Approach to Synthesizing Covariance Matrices in Meta-Analytic Structural Equation Modeling. *Structural Equation Modeling: A Multidisciplinary Journal*, 16(1), 28–53. https://doi.org/10.1080/10705510802561295

Chou, W. J., Liu, T. L., Yang, P., Yen, C. F., & Hu, H. F. (2015). Multi-dimensional correlates of Internet addiction symptoms in adolescents with attention-deficit/hyperactivity disorder. *Psychiatry research*, 225(1-2), 122-128.

Chou, W. J., Huang, M. F., Chang, Y. P., Chen, Y. M., Hu, H. F., & Yen, C. F. (2016). Social skills deficits and their association with Internet addiction and activities in adolescents with attention-deficit/hyperactivity disorder. *Journal of Behavioral Addictions*, *6*(1), 42-50.

Chou, W. J., Chang, Y. P., & Yen, C. F. (2018). Boredom proneness and its correlation with Internet addiction and Internet activities in adolescents with attention-deficit/hyperactivity disorder. *The Kaohsiung Journal of Medical Sciences*, 34(8), 467-474.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum

Collett, B. R., Ohan, J. L., & Myers, K. M. (2003). Ten-year review of rating scales. V: Scales assessing attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, *42*(9), 1015-1037.

Demirtaş, O. O., Alnak, A., & Coşkun, M. (2021). Lifetime depressive and current social anxiety are associated with problematic internet use in adolescents with ADHD: A cross-sectional study. *Child and Adolescent Mental Health*, *26*(3), 220-227.

DuPaul, G. J., Power, T. J., Anastopoulos, A. D., & Reid, R. (1998). *ADHD Rating Scale—IV: Checklists, norms, and clinical interpretation. Guilford Press*.

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.

Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, *56*, 455–463.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ*, *315,* 629–634.

Ferguson, C. J., & Colwell, J. (2020). Lack of consensus among scholars on the issue of video game "addiction". *Psychology of Popular Media, 9*(3), 359-366. https://doi.org/10.1037/ppm0000243

Galanis, C. R., Delfabbro, P. H., & King, D. L. (2021). Stigma-related arguments against gaming disorder: A call for research. *Addiction, 116(*10), 2921-2922. https://doi.org/10.1111/add.15561

Gao, X., Zhang, M., Yang, Z., Wen, M., Huang, H., Zheng, R., ... & Zhang, Y. (2021). Structural and functional brain abnormalities in internet gaming disorder and attention-deficit/hyperactivity disorder: a comparative meta-analysis. *Frontiers in Psychiatry*, 964. https://doi.org/10.3389/fpsyt.2021.679437

Gershon, J., & Gershon, J. (2002). A meta-analytic review of gender differences in ADHD. *Journal of Attention Disorders*, *5*(3), 143-154.

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.

Griffiths, M. D., van Rooij, A. J., Kardefelt-Winther, D., Starcevic, V., Király, O., Pallesen, S., . . . Demetrovics, Z. (2016). Working towards an international consensus on criteria for assessing Internet Gaming Disorder: A critical commentary on Petry et al (2014). *Addiction, 111*(1), 167-175.

Han, D. H., Yoo, M., Renshaw, P. F., & Petry, N. M. (2018). A cohort study of patients seeking Internet gaming disorder treatment. *Journal of Behavioral Addictions*, 7(4), 930-938.

Harrer, M., Cuijpers, P., Furukawa, T. A., & Ebert, D. D. (2021). *Doing Meta-Analysis with R*. https://doi.org/10.1201/9781003107347

Hupfeld, K. E., Abagis, T. R., & Shah, P. (2019). Living "in the zone": hyperfocus in adult ADHD. *ADHD Attention Deficit and Hyperactivity Disorders*, 11, 191-208. https://doi.org/10.1007/s12402-018-0272-y

Jeong, H., Yim, H. W., Lee, S.-Y., Lee, H. K., Potenza, M. N., Jo, S.-J., . . . Kim, G. (2020). Low self-control and aggression exert serial mediation between inattention/hyperactivity problems and severity of internet gaming disorder features longitudinally among adolescents. *Journal of Behavioral Addictions, 9*(2), 401-409.

Jung, D., Shim, E. J., Park, H., Lee, K., Lee, S., Kim, E. Y., ... & Hahm, B. J. (2020). The association between excessive internet gaming behavior and immersive tendency, mediated by attention deficit/hyperactivity disorder symptoms, in korean male university students. *Psychiatry Investigation*, 17(5), 403-411.

Karaca, S., Saleh, A., Canan, F., & Potenza, M. N. (2017). Comorbidity between behavioral addictions and attention deficit/hyperactivity disorder: A systematic review. *International Journal of Mental Health and Addiction*, *15*(3), 701-724.

Kessler, R. C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E. V. A., ... & Walters, E. E. (2005). The World Health Organization Adult ADHD Self-Report Scale (ASRS): A short screening scale for use in the general population. *Psychological Medicine*, *35*(2), 245-256.

Kim, H. S., Son, G., Roh, E. B., Ahn, W. Y., Kim, J., Shin, S. H., ... & Choi, K. H. (2022). Prevalence of gaming disorder: A meta-analysis. *Addictive Behaviors*, 126, 107183.

King, D. L., Haagsma, M. C., Delfabbro, P. H., Gradisar, M., & Griffiths, M. D. (2013). Toward a consensus definition of pathological video-gaming: A systematic review of psychometric assessment tools. *Clinical Psychology Review*, *33*(3), 331-342.

King, D. L., Chamberlain, S. R., Carragher, N., Billieux, J., Stein, D., Mueller, K., ... & Delfabbro, P. H. (2020). Screening and assessment tools for gaming disorder: A comprehensive systematic review. *Clinical Psychology Review, 77,* 101831.

Király, O., Bőthe, B., Ramos-Diaz, J., Rahimi-Movaghar, A., Lukavska, K., Hrabec, O., ... & Demetrovics, Z. (2019). Ten-Item Internet Gaming Disorder Test (IGDT-10): Measurement invariance and cross-cultural validation across seven language-based samples. *Psychology of Addictive Behaviors*, *33*(1), 91-103.

Király, O., Griffiths, M. D., & Demetrovics, Z. (2015). Internet gaming disorder and the DSM-5: Conceptualization, debates, and controversies. *Current Addiction Reports, 2*(3), 254-262. https://doi.org/10.1007/s40429-015-0066-7.

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.* https://doi.org/10.1556/2006.2022.00048

Király, O., Sleczka, P., Pontes, H. M., Urbán, R., Griffiths, M. D., & Demetrovics, Z. (2017). Validation of the Ten-Item Internet Gaming Disorder Test (IGDT-10) and evaluation of the nine DSM-5 Internet Gaming Disorder criteria. *Addictive Behaviors, 64*, 253-260. https://doi.org/10.1016/j.addbeh.2015.11.005

Király, O., Koncz, P., Griffiths, M. D., & Demetrovics, Z. (2023). Gaming disorder: A summary of its characteristics and aetiology. *Comprehensive Psychiatry*, 122, 152376. https://doi.org/10.1016/j.comppsych.2023.152376

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

Koyuncu, A., Ertekin, E., Yüksel, Ç., Aslantaş Ertekin, B., Çelebi, F., Binbay, Z., & Tükel, R. (2015). Predominantly inattentive type of ADHD is associated with social anxiety disorder. *Journal of Attention Disorders*, *19*(10), 856-864.

Kräplin, A., Scherbaum, S., Kraft, E. M., Rehbein, F., Bühringer, G., Goschke, T., & Mößle, T. (2021). The role of inhibitory control and decision-making in the course of Internet gaming disorder. *Journal of behavioral addictions*, 9(4), 990-1001.

Laconi, S., Rodgers, R. F., & Chabrol, H. (2014). The measurement of Internet addiction: A critical review of existing scales and their psychometric properties. *Computers in Human Behavior*, *41,* 190-202.

Li, W., Zhang, W., Xiao, L., & Nie, J. (2016). The association of Internet addiction symptoms with impulsiveness, loneliness, novelty seeking and behavioral inhibition system among adults with attention-deficit/hyperactivity disorder (ADHD). *Psychiatry Research*, *243*, 357-364.

Malkovsky, E., Merrifield, C., Goldberg, Y., & Danckert, J. (2012). Exploring the relationship between boredom and sustained attention. *Experimental Brain Research*, 221, 59-67. https://doi.org/10.1007/s00221-012-3147-z

Marmet, S., Studer, J., Grazioli, V. S., & Gmel, G. (2018). Bidirectional associations between self-reported gaming disorder and adult attention deficit hyperactivity disorder: Evidence from a sample of young Swiss men. *Frontiers in Psychiatry*, *9,* 649.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group*. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, *151*(4), 264-269.

Murray, A., Koronczai, B., Király, O., Griffiths, M. D., Mannion, A., Leader, G., & Demetrovics, Z. (2021). Autism, problematic internet use and gaming disorder: A systematic review. *Review Journal of Autism and Developmental Disorders*, 9, 120-130.

Nijmeijer, J. S., Minderaa, R. B., Buitelaar, J. K., Mulligan, A., Hartman, C. A., & Hoekstra, P. J. (2008). Attention-deficit/hyperactivity disorder and social dysfunctioning. *Clinical psychology review*, 28(4), 692-708.

Ostinelli, E. G., Zangani, C., Giordano, B., Maestri, D., Gambini, O., D'Agostino, A., ... & Purgato, M. (2021). Depressive symptoms and depression in individuals with internet gaming disorder: A systematic review and meta-analysis. *Journal of Affective Disorders*, *284,* 136-142.

Pontes, H. M., & Griffiths, M. D. (2015). Measuring DSM-5 internet gaming disorder: Development and validation of a short psychometric scale. *Computers in Human Behavior, 45,* 137-143.

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin*, *86*, 638-6141.

Savard, J., Hirvikoski, T., Görts Öberg, K., Dhejne, C., Rahm, C., & Jokinen, J. (2021). Impulsivity in compulsive sexual behavior disorder and pedophilic disorder. *Journal of Behavioral Addictions, 10*(3), 839-847.

Schettler, L., Thomasius, R., & Paschke, K. (2022). Neural correlates of problematic gaming in adolescents: A systematic review of structural and functional magnetic resonance imaging studies. *Addiction Biology, 27*(1), e13093.

Simon, V., Czobor, P., Bálint, S., Mészáros, A., & Bitter, I. (2009). Prevalence and correlates of adult attention-deficit hyperactivity disorder: meta-analysis. *British Journal of Psychiatry*, *194*(3), 204-211.

Sonuga-Barke, E. J. (2002). Psychological heterogeneity in AD/HD—a dual pathway model of behaviour and cognition. *Behavioural brain research*, 130(1-2), 29-36.

Stander, V. A., Thomsen, C. J., & Highfill-McRoy, R. M. (2014). Etiology of depression comorbidity in combat-related PTSD: a review of the literature. *Clinical psychology review*, *34*(2), 87-98.

Stevens, M. W., Dorstyn, D., Delfabbro, P. H., & King, D. L. (2021). Global prevalence of gaming disorder: A systematic review and meta-analysis. *Australian & New Zealand Journal of Psychiatry*, *55*(6), 553-568.

Taylor, A., Deb, S., & Unwin, G. (2011). Scales for the identification of adults with attention deficit hyperactivity disorder (ADHD): A systematic review. *Research in Developmental Disabilities*, *32*(3), 924-938.

Tejeiro Salguero, R. A., & Morán, R. M. B. (2002). Measuring problem video game playing in adolescents. *Addiction*, *97*(12), 1601-1606.

Theule, J., Hurl, K. E., Cheung, K., Ward, M., & Henrikson, B. (2019). Exploring the relationships between problem gambling and ADHD: A meta-analysis. *Journal of Attention Disorders*, *23*(12), 1427-1437.

Thomas, R., Sanders, S., Doust, J., Beller, E., & Glasziou, P. (2015). Prevalence of attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. *Pediatrics*, *135*(4), e994-e1001.

Tzang, R. F., Chang, C. H., & Chang, Y. C. (2022). Structural equation modeling (SEM): Gaming disorder leading untreated attention-deficit/hyperactivity disorder to disruptive mood dysregulation. *International Journal of Environmental Research and Public Health*, *19*(11), 6648.

Ustun, B., Adler, L. A., Rudin, C., Faraone, S. V., Spencer, T. J., Berglund, P., ... & Kessler, R. C. (2017). The World Health Organization adult attention-deficit/hyperactivity disorder self-report screening scale for DSM-5. *JAMA Psychiatry, 74*(5), 520-526.

van Emmerik-van Oortmerssen, K., van de Glind, G., van den Brink, W., Smit, F., Crunelle, C. L., Swets, M., & Schoevers, R. A. (2012). Prevalence of attention-deficit hyperactivity disorder in substance use disorder patients: A meta-analysis and meta-regression analysis. *Drug and Alcohol Dependence*, *122*(1-2), 11-19.

Van Rooij, A. J., Schoenmakers, T. M., & Van de Mheen, D. (2017). Clinical validation of the C-VAT 2.0 assessment tool for gaming disorder: A sensitivity analysis of the proposed DSM-5 criteria and the clinical characteristics of young patients with 'video game addiction'. *Addictive Behaviors*, 64, 269-274. https://doi.org/10.1016/j.addbeh.2015.10.018

Volkow, N. D., Wang, G. J., Newcorn, J. H., Kollins, S. H., Wigal, T. L., Telang, F., ... & Swanson, J. M. (2011). Motivation deficit in ADHD is associated with dysfunction of the dopamine reward pathway. *Molecular psychiatry*, 16(11), 1147-1154.

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.

Willcutt, E. G. (2012). The prevalence of DSM-IV attention-deficit/hyperactivity disorder: A meta-analytic review. *Neurotherapeutics*, 9(3), 490-499.

World Health Organization (2019). *ICD-11: International classification of diseases (11th revision)*. https://icd.who.int/browse11/l-m/en#/http://id.who.int/icd/entity/1448597234

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

Young, K. S. (1998). *Caught in the net: How to recognize the signs of internet addiction-and a winning strategy for recovery*. John Wiley & Sons.