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A systematic review of problematic video-game use in people with Autism Spectrum Disorders

Francesco Craig [a,*], Flaviana Tenuta [a], Andrea De Giacomo [b], Antonio Trabacca [c], Angela Costabile [a]

[a] Department of Cultures, Education and Society, University of Calabria, Cosenza, Italy
[b] Child Neuropsychiatry Unit, Department of Basic Medical Sciences, Neuroscience and Sense Organs, University of Bari "Aldo Moro", Bari, Italy
[c] Scientific Institute, IRCCS E. Medea, Unit for Severe Disabilities in Developmental Age and Young Adults, Brindisi, Italy

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ABSTRACT

Background: In recent years, an increasing number of studies documented potential links between gaming disorders (GD; including "digital-gaming" or "video-gaming") and Autism Spectrum Disorders (ASD). Therefore, the aim of this systematic review was to summarize current research about problematic video game (PVG) use in people with ASD and identify specific factors associated with problematic video gaming behavior.

Method: We searched for articles indexed in PubMed, Scopus, Web of Science, and EBSCOhost electronic databases; using a combination of expressions including "autism spectrum disorder" OR "autism" OR "ASD" AND "video games" OR "gaming disorder" OR "Internet Gaming Disorder" OR "game addiction".

Results: Twelve articles were included in this systematic review. The majority of them indicate that children, adolescents and adults with ASD may be at greater risk of PVG use than youths without ASD. Findings also suggested that several internal (sex, attention and oppositional behavior problems) and external factors (social aspects, access and time spent playing video, parental rules, and game genre) were significant predictors of problematic video game use in people with ASD. In addition, this review highlights the paucity of the literature on the consequences and individual effects of excessive video gaming in people with ASD.

Conclusions: We discuss unanswered questions and future directions and provide recommendations for improving clinicians and parents' engagement in the prevention and management of problematic video game use in people with ASD.

1. Introduction

Autism spectrum disorders (ASD) is a complex lifelong condition that involves persistent challenges in social communication and interaction and restricted repetitive behaviors (American Psychiatric Association, 2013). Although ASD has a strong genetic component, as indicated by the recurrence risk in families and in twin studies (Castelbaum, Sylvester, Zhang, Yu, & Constantino, 2020), co-occurring difficulties may influence behavioral phenotype (Chaste & Leboyer, 2012). Thus, identifying factors that affect

* Corresponding author at: University of Calabria (UNICAL), Department of Cultures, Education and Society, Via Pietro Bucci, 87036 Arcavacata, Rende CS, Italy.
E-mail address: FRANCESCO.CRAIG@UNICAL.IT (F. Craig).

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socio-behavioral regulation, health, and daily functioning in people with ASD is of chief concern. Among potentially relevant factors, excessive and problematic use of video game may be an important consideration. (Gonzalez-Bueso et al., 2018).

Mental health professionals identified problematic use of video games as an addictive behavior with clinical relevance in several functional areas such as relationship conflicts, social isolation, sleep problems, fatigue, poor school performance or vocational achievement in a working context (King et al., 2019; Lam, 2014). Recently, the World Health Organization (WHO) included gaming disorder (Table 1) in their International Classification of Diseases (ICD-11; World Health Organization, 2020). Gaming disorder (GD) is defined as a pattern of gaming behavior ("digital gaming" or "video gaming") characterized by impaired control over gaming, increasing priority given to gaming over other activities to the extent that gaming takes precedence over other interests and daily activities, and continuation or escalation of gaming despite the occurrence of negative consequences (Kircaburun, Pontes, Stavropoulos, & Griffiths, 2020). GD shares similarities with internet gaming disorder (IGD), which the American Psychiatric Association (APA) labeled as a condition requiring further studies in their Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2013). The DSM-5 (Table 1) notes that gaming must cause "significant impairment or distress" in several aspects of a person's life. This proposed condition is limited to gaming and does not include problems with general use of the internet, online gambling, or use of social media or smartphones.

The APA does not currently recognize IGD as an official condition; however, a growing body of research looks at it as a disorder, suggesting new strategies for prevention, diagnosis and treatment (Gentile et al., 2017; Zajac, Ginley, Chang, & Petry, 2017). Over time, there has been some confusion over the definition of addictive gaming and a range of terminology is now in use to identify problematic video game use, including pathological video game use or gaming, problem video game playing, online gaming addiction, video game addiction, IGD, and compulsive Internet use. For this reason, in the current review we use the term "problematic video game (PVG) use" as an umbrella term comprising a wide range of constructs.

PVG users are likely to suffer from a greater number of mental health problems such as depression, anxiety, negative self-esteem, behavioral problems, and even game addiction (von der Heiden, Braun, Muller, & Egloff, 2019). Excessive or compulsive use of video games has also emerged as a major concern for children, adolescents and young people showing characteristics similar to other forms of dependency (Sussman, Harper, Stahl, & Weigle, 2018; von der Heiden et al., 2019). Recent evidence suggests that PVG use is common in people with neurodevelopmental disorders (Andreassen et al., 2016; Gonzalez-Bueso et al., 2018). The core symptoms of ASD may be directly related to the development of problematic video game play patterns (Engelhardt, Mazurek, & Sohl, 2013; Mazurek & Engelhardt, 2013b). Engagement in restricted and repetitive interests may lead to difficulty disengaging from video games (Mazurek, Shattuck, Wagner, & Cooper, 2012). Given their audiovisual and structural characteristics and the fact that they are associated with low social demands, video games may be particularly rewarding for people with ASD (Mazurek & Engelhardt, 2013b). Until recently, researchers held that addiction problems in people with ASD are rare; however, recent evidence suggests that people with ASD having average or above-average intelligence quotients (IQs) are more likely to develop addictive disorders and other stimulatory behaviors such as video gaming, watching television and internet use (Matson, 2017). This assumption is reinforced by

Table 1
Criteria for ICD-11 Gaming Disorder and DSM-5 (Internet) Gaming Disorder.

(ICD-11)	DSM-5
Gaming disorder is characterised by a pattern of persistent or recurrent gaming behaviour ('digital gaming' or 'video-gaming'), which may be online (i.e., over the internet) or offline, manifested by:	The DSM-5 notes that gaming must cause "significant impairment or distress" in several aspects of a person's life. This proposed condition is limited to gaming and does not include problems with general use of the internet, online gambling, or use of social media or smartphones. The proposed symptoms of internet gaming disorder include:
1. impaired control over gaming (e.g., onset, frequency, intensity, duration, termination, context);	Preoccupation with gaming
2. increasing priority given to gaming to the extent that gaming takes precedence over other life interests and daily activities;	Withdrawal symptoms when gaming is taken away or not possible (sadness, anxiety, irritability)
3. continuation or escalation of gaming despite the occurrence of negative consequences.	Tolerance, the need to spend more time gaming to satisfy the urge
The pattern of gaming behaviour may be continuous or episodic and recurrent.	Inability to reduce playing, unsuccessful attempts to quit gaming
The pattern of gaming behaviour results in marked distress or significant impairment in personal, family, social, educational, occupational, or other important areas of functioning.	Giving up other activities, loss of interest in previously enjoyed activities due to gaming
The gaming behaviour and other features are normally evident over a period of at least 12 months in order for a diagnosis to be assigned, although the required duration may be shortened if all diagnostic requirements are met and symptoms are severe.	Continuing to game despite problems
	Deceiving family members or others about the amount of time spent on gaming
	The use of gaming to relieve negative moods, such as guilt or hopelessness
	Risk, having jeopardized or lost a job or relationship due to gaming
	Under the proposed criteria, a diagnosis of internet gaming disorder would require experiencing five or more of these symptoms within a year. The condition can include gaming on the internet, or on any electronic device, although most people who develop clinically significant gaming problems play primarily on the internet.

International Classification of Diseases 11th Revision (ICD-11), Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5).

evidence pointing out that people with ASD spend more time playing video games than typically developing (TD) people do (Engelhardt et al., 2013), and they are more likely to become obsessive with play video games than TD people are (Mazurek & Engelhardt, 2013a). Neurobiological studies suggest that addiction disorders predominantly involve dopamine release within the nucleus accumbens (Koob & Volkow, 2016) and this activity is mediated by limbic circuits, particularly the amygdala, and other brain regions such as the dorsolateral and orbitofrontal cortex, temporoparietal junction and anterior cingulate gyrus. Recent brain activation studies have shown that videogame playing involved changes in reward and loss of control and that gaming pictures have activated regions similarly to those activated by cue exposure to drugs (Brilliant, Nouchi, & Kawashima, 2019). Similarly, some researchers found that subjects with ASD have abnormal brain activities that would lead to deficits in inhibition of responses and emotional processes (Ha, Sohn, Kim, Sim, & Cheon, 2015) resulting in lack of self-control, meaning that video game users would become more unable to restrain themselves and vulnerable to gaming disorder (Weinstein & Lejoyeux, 2015). Furthermore, the social motivation hypothesis suggests that people with ASD find social stimuli less rewarding than do people with neurotypical activity (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). The imbalance between motivation for social versus non-social stimuli is reflected in the responsiveness of the brain's reward system (Kohls, Yerys, & Schultz, 2014). According to the social motivation hypothesis, Kohls, Antezana, Mosner, Schultz, and Yerys (2018) showed in an fMRI study that individuals with ASD had stronger reward system responses for circumscribed interests mostly within the non-social realm (e.g., video games) than social rewards (e.g., approval) compared with TD people. In addition, they found that atypical reward system responses, most pronounced within the caudate nucleus, were related to greater social impairment. In other words, impairments in the brain's reward circuitry in individuals with ASD might reduce their experience with social interactions and the attention they pay to social information, setting in motion developmental processes that ultimately deprive them of adequate social learning opportunities (Chevallier et al., 2012; Clements et al., 2018). This, in turn, could reflect in individuals with ASD a greater preference for nonsocial objects related to restricted interests (Watson et al., 2015). Hence, these findings indicate that some brain mechanisms in ASD could be a possible risk factor that may lead to PVG use.

Clinically, parents of children and adolescents with ASD frequently ask for guidance regarding use of video games and its potential impact on their children's functioning (Mazurek & Engelhardt, 2013b). There is emerging evidence that problematic video game use is associated with certain comorbid conditions such as anxiety, emotional blunting towards violence, social withdrawal, decreased helpfulness and lack of empathy (Gao, Weng, Zhou, & Yu, 2017; Wang, Sheng, & Wang, 2019). In addition, management of video gaming is a major issue for parents, causing stress within families (Krossbakken et al., 2018), and parental dysfunctional coping strategies over media use might affect the likelihood for children or adolescents to become problem gamers (Schneider, King, & Delfabbro, 2017; Stockdale & Coyne, 2020). Thus, understanding parents' experiences can be an important first step to support their management of video game use.

1.1. Aim

Given the large increase in research examining disordered gaming in individuals with ASD, there is a need for a systematic review of problematic video game use in children, adolescent and adults with ASD. We therefore decided to review the scientific literature on video game use to provide an up-to-date overview of gaming disorder in people with ASD. More specifically, the main aims of the current review were to: (a) evaluate PVG use in people with ASD; (b) identify internal or external factors associated with video game use in ASD; (c) examine the interrelationship and effect of video game use in people with ASD; (d) provide recommendations for clinical practice and future research.

2. Methods

2.1. Study selection and data collection processes

The systematic review was conducted according to the structured Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews (Liberati et al., 2009). The search strategy included research databases such as PubMed, Scopus, Web of Science, and EBSCOhost. All database searches were performed on February 6th, 2020 using a combination of the following free-text terms:"autism spectrum disorder" OR "autism" OR "ASD" AND "video games" OR "gaming disorder" OR "Internet Gaming Disorder" OR "game addiction". After this initial literature search, each single study title and abstract was screened by the first author. All references with duplicate data were excluded. Based on eligibility criteria, two reviewers (FC and FT) independently screened an abstract of available citations to identify potentially eligible studies. The full text of all potentially relevant studies was subsequently retrieved and further examined for eligibility. All references included in the papers identified as relevant from the database search were also examined for possible inclusion in this review. Data were extracted independently by three authors (FC, FT, AC) and disagreements were resolved by negotiation with a fourth author (AT). Agreement as to whether or not the study met the inclusion criteria was 100%.

2.2. Eligibility criteria

All the studies included in this review met the following five criteria: They (1) investigated the associations between ASD and video gaming; (2) included children or adolescents or adults with ASD; (3) described video game use (frequency, amount of time, content, access, and companions); (4) examined internal and external factors; (5) were published in peer-reviewed journals. We focused on

aetiological factors related to developing and maintaining a PVG use. Individual socio-demographic and clinical characteristics were considered as internal factors, while social, familial, and game-related factors were included in external factors. Exclusion criteria were as follows: Studies were not to (a) report original research (case report, review, oral communications, letter, poster, doctoral dissertations or master's theses), (b) include mixed results (e.g. internet, television, social network) without differentiating results for video games; (c) focus only on clinical intervention or rehabilitation treatment; (d) report irrelevant goals and outcomes (e.g. video game use to understand social behaviors, physical activity, motor, and neurocognitive skills in people with ASD), (e) be in a language other than English, (f) no access to full text. There was no date range limitation applied due to the need to identify all potentially relevant studies from a small body of literature.

2.3. Data extraction

Studies meeting the inclusion criteria were summarized in terms of authors, year of publication, type of study, number of participants (sample size), diagnosis-related groups, country where data were collected, population characteristics, age, sex, tools used to measure video game use, PVG use, frequency and amount of time spent playing video games, genre of video games, companions, sex differences, access to video game system, other outcomes and main findings.

2.4. Risk of bias in individual studies

Included studies were evaluated for a risk of bias using the Effective Public Health Practice Project (EPHPP, 1998) Quality Assessment Tool for Quantitative Studies. The EPHPP is a standardized tool used to evaluate the quality of quantitative observational studies. We evaluated six domains of study validity: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Each domain can be rated as strong, moderate, or weak. Once the assessment is fulfilled, each examined paper receives a mark ranging between "strong (no WEAK ratings)", "moderate (one WEAK rating)" and "weak (two or more WEAK ratings)". The quality of all included studies was assessed by the first author. Two independent judges (FT, ADG) completed the questionnaires. Differences in quality assessment were resolved by discussion among all of the authors. The level of interrater agreement was assessed by the kappa coefficient. The interrater agreement was 92% (κ 0.85). Disagreement was resolved by discussion.

3. Results

A flow chart of the literature selection process is summarized in Fig. 1. 767 papers (PubMed n = 29, Scopus n = 205, Web of Science n = 495, EBSCOhost n = 38) published in the time period between January 2010 and February 2020 were identified. After omitting duplicates, we identified 452 potential articles. Titles and abstracts of all identified studies were examined. This led to the exclusion of 424 studies, as they were not deemed suitable for the present review.

A total of 28 articles proceeded to full text review. Out of these, 16 studies were excluded because they did not meet selection criteria. Following this procedure, 12 articles were ultimately identified as relevant to our research.

3.1. Study characteristics and methodology

Table 2 contains the general characteristics and main methodological features of all reviewed studies.

Four studies involved only individuals with ASD, seven studies compared ASD people with individuals with typical development, and three studies compared children and adolescents with ASD and children with other neurodevelopmental conditions such as Attention deficit hyperactivity disorder (ADHD), speech/language impairment (SL), learning disability (LD), and intellectual disabilities (ID). One study enrolled adults or young adults, and eleven studies included only children and adolescents ranging from 9 to 17 years of age.

The majority of studies had case-control designs (n = 6), followed by cross-sectional designs (n = 5) and a longitudinal design (n = 1), and more than one statistical method was used to examine PVG use in ASD or to identify internal or external factors associated with video game use in ASD. Eleven studies examined differences in PVG use in people with ASD, TD peers, and children with others neurodevelopmental conditions. Six studies performed correlation analysis to investigate the relationships between internal or external factors and PVG use in people with ASD. Five studies performed regression analysis to explore the predictor role of internal or external factors on PVG use in people with ASD. One study investigated potential mediators of the relationship between internal or external factors and problematic or excessive gaming in ASD, and another study examined parental rules as potential moderator relations between internal or external factors and behavioral outcome.

The included studies were conducted in the USA (n = 8), Canada (n = 3) and Germany (n = 1).

3.2. Diagnostic criteria and assessment tools

Table 2 contains the main methodological features of all reviewed studies. ASD can potentially be assessed both categorically and dimensionally. The gold standards for the diagnosis of ASD, the Autism Diagnostic Interview – Revised (ADI-R; Le Couteur, Lord, & Rutter, 2003) and the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2001), were used in four studies. The Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was used in six studies, and the Autism Quotient (AQ;

Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) was used in one study.

Of the 12 studies investigating PVG use in ASD populations, five studies used psychometric tools. Three of these studies used the Problem Video Game Playing Test (PVGT; Tejeiro Salguero & Moran, 2002), one used the Pathological Video Game Use Questionnaire (PVGUQ; Gentile, 2009), and one used the Compulsive Internet Use Scale (CIUS; Meerkerk, Van Den Eijnden, Vermulst, & Garretsen, 2009). Eleven studies developed and used a number of ad-hoc questionnaires to assess multiple facets of video game use such as frequency and time spent to play, video game categories, companions, in-room access, and types of electronic devices. Only one study used 24-h media-use diaries adapted from a measures successfully used for TD children and adolescents.

3.3. Methodological quality assessment

According to the EPHPP quality assessment tool, eight studies were of moderate methodological quality, three studies were of low methodological quality, and one study was of high methodological quality. Low ratings were mostly attributable to the validity and reliability of data collection tools or methods; causes included the use of ad-hoc questionnaires and non-standardized measures or criteria. Other methodological limitations included the study design and the missing numbers of withdrawals and dropouts. Quality assessment scores and additional adjustments made by individual studies are presented in Table 3.

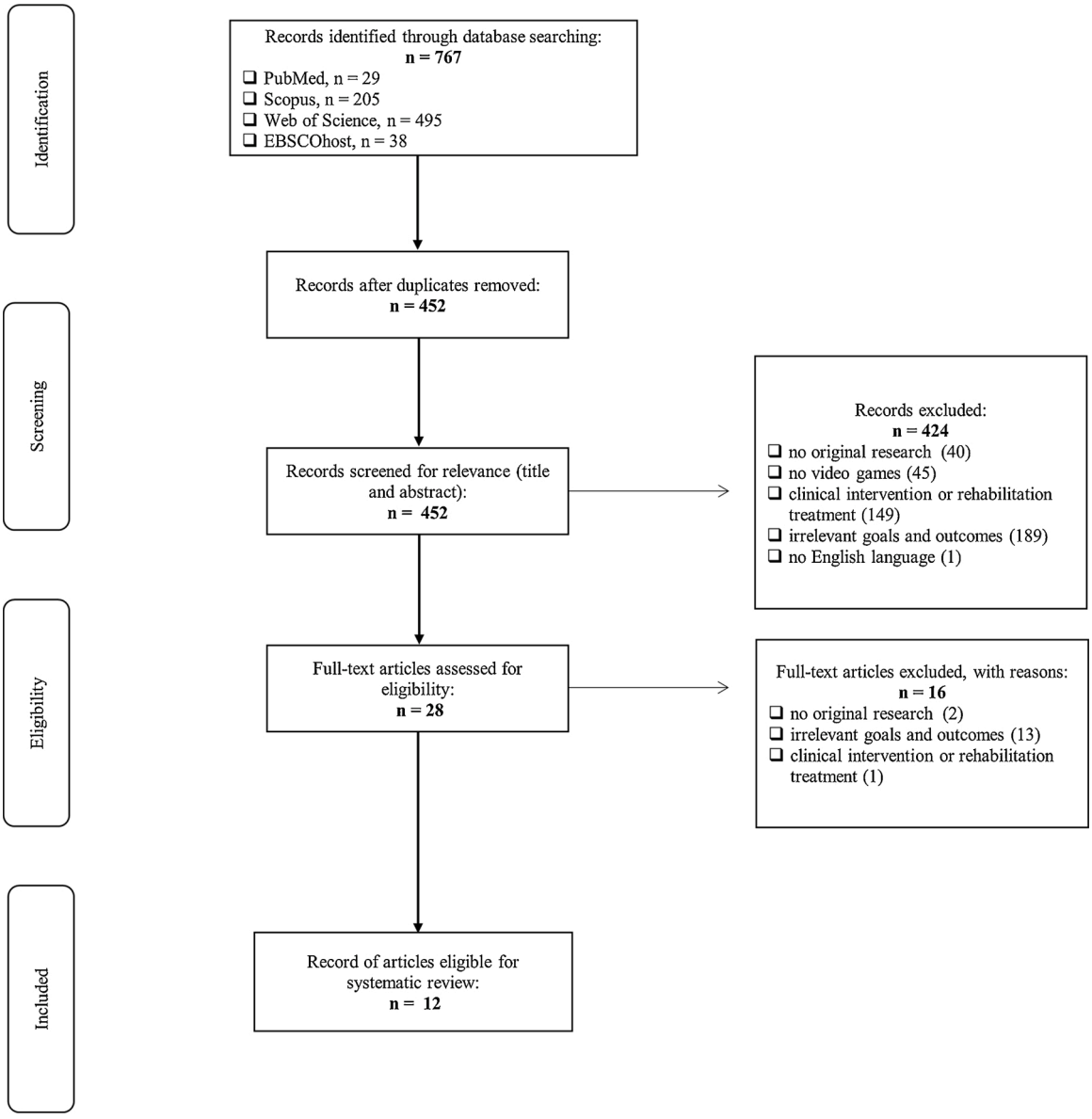

Fig. 1. Flow Diagram summarizing the article selection process.

Table 2
Summary of main characteristics of the studies included in the systematic review.

Authors, year of publication	Type of study	Number of participants (N)	Diagnosis-related groups	Country	Age	Sex	assessment tools (ASD)	assessment tools (PVG)	Statistical analysis
Mazurek et al. (2012)	case-control	3510	920 (ASD), 860 (SL), 880 (LD), 850 (MR)	USA	13 to 17 years	M: 782 (ASD), 535 (SL), 591 (LD), 485 (MR); F: 138 (ASD), 325 (SL), 289 (LD), 365 (MR)	DSM-IV	ad hoc questionnaire (Screen-based media use)	Comparison, Regression analysis
Engelhardt et al. (2013)	case-control	128	49 (ASD), 38 (ADHD), 41 (TD)	USA	11.8 ± 2.7 (ASD); 11.3 ± 2.5 (ADHD); 12.2 ± 2.4 (TD)	128 M	ADOS, ADI, SCQ	ad hoc questionnaire (in-room access, hs play)	Comparison, Correlation, Mediation analyses
Mazurek and Wenstrup (2013)	case-control	381	202 (ASD), 179 (sibling)	USA	12.1 ± 2.8 (ASD), 12.5 ± 2.6 (sibling)	M: 169 (ASD), 88 (sibling); F: 33 (ASD), 91 (sibling)	SCQ, ADOS, ADI-R	PVGT, ad hoc questionnaire (Time Spent, Video Game Use Patterns and Types)	Comparison analyses
Mazurek and Engelhardt (2013a)	case-control	141	56 (ASD), 44 (ADHD), 41 (TD)	USA	11.7 ± 2.6 (ASD), 11.1 ± 2.4 (ADHD), 12.2 ± 2.4 (TD)	141 M	ADOS, ADI, SCQ	PVGT	Comparison, Correlation, Regression analyses
Mazurek and Engelhardt (2013b)	cross-sectional	169	ASD	USA	12.1 ± 2.8	169 M	N/A	PVGT, ad hoc questionnaire (Video game use)	Correlation, Regression analyses
Kuo et al. (2014)	cross-sectional	91	ASD	Canada	14.8 ± 1.9	74 M, 17 F	SCQ	ad hoc questionnaire (Media use)	Descriptive, Comparioson analysis
Engelhardt and Mazurek (2014)	cross-sectional	169	ASD	USA	12.1 ± 2.8	169 M	N/A	ad hoc questionnaire (In-room access to screen-based media, time spent, Parental rules)	Comparison, Regression, Moderation analysis
Kuo et al. (2015)	longitudinal	45	29 (ASD), 16 (siblings)	Canada	15.1 ± 2.3 (ASD), 14.4 ± 2.2 (sibling)	M: 26 (ASD), 8 (sibling); F: 3 (ASD), 8 (sibling)	DSM-IV-TR, SCQ	ad hoc questionnaire (Time spent, parent strategies), media-use diaries based on ACMA, video game mediation measure	Comparison, Correlation analyses
Finke et al. (2015)	cross-sectional	152	ASD	USA	9.8 years	141 M, 11 F	N/A	ad hoc questionnaire (video gaming preferences and behaviors)	Comparison, Correlation analysis
MacMullin et al. (2016)	case-control	310	138 (ASD), 172 (TD)	Canada	11.72 ± 3.61 (ASD), 12.25 ± 3.97 (TD)	M: 115 (ASD), 134 (TD); F: 23 (ASD), 38 (TD)	SCQ, DSM-IV-TR	CIUS, ad hoc questionnaire (Electronics use and impact)	Comparison analyses
Engelhardt et al. (2017)	case-control	119	60 (ASD), 59 (TD)	USA	20.42 (ASD); 20.54 (TD)	M: 51 (ASD), 51 (TD); F: 9 (ASD), 8(TD)	ADOS, ADI, AQ	ad hoc questionnaire (Video game use), adapted from PVGUQ	Comparison, Correlation, Regression analyses
Paulus et al. (2020)	cross-sectional	93	62 (ASD), 31 (TD)	Germany	11.5 ± 3.2 (ASD), 11.5 ± 3.7 (TD)	93 M	N/A	ad hoc questionnaire (video game use, DSM-5-video gaming behavior)	Comparison analyses

Groups: Autism Spectrum Disorders (ASD), Attention deficit hyperactivity disorder (ADHD), Speech/language impairment (SL), Learning disability (LD), intellectual disabilities (ID), typically developing (TD).
Tools: Social Communication Questionnaire (SCQ), Social and Communication Disorders Checklist (SCDC), Autism Quotient (AQ), Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview-Revised (ADI-R), Pathological Video Game Use Questionnaire (PVGUQ); Australian Communications and Media Authority (ACMA), Compulsive Internet Use Scale (CIUS), Problem Video Game Playing Test (PVGT).
Other: not applicable (N/A), males (M), females (F), Pathological video-game (PVG).

Table 3
Results of quality assessment of studies using the EPHPP[a] Quality Assessment Tool for Quantitative Studies.

Authors, year of publication	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Global rating
Mazurek et al. (2012)	1	2	1	2	3	2	2
Engelhardt et al. (2013)	2	2	1	2	2	3	2
Mazurek and Wenstrup (2013)	1	2	1	2	1	3	2
Mazurek and Engelhardt (2013a)	2	2	1	2	1	3	2
Mazurek and Engelhardt (2013b)	1	3	1	2	2	N/A	2
Kuo et al. (2014)	2	3	2	2	3	N/A	3
Engelhardt and Mazurek (2014)	2	3	1	2	3	N/A	3
Kuo et al. (2015)	3	1	1	1	2	2	2
Finke et al. (2015)	2	3	1	2	3	N/A	3
MacMullin et al. (2016)	2	2	1	2	1	1	1
Engelhardt et al. (2017)	2	2	1	2	1	3	2
Paulus et al. (2020)	2	2	1	2	3	N/A	2

[a] EPHPP: Effective Public Health Practice Project, Not Applicable (N/A).

3.4. Problematic video-game use

We found six studies evaluating the prevalence of PVG use (Table 4) in people with ASD.

A cross-sectional study (Engelhardt, Mazurek, & Hilgard, 2017) examined whether adults with ASD are at higher risk for PVG use than TD adults. The study included 119 adults (16 women), half of whom had a previous diagnosis of ASD, participating in a larger study on violent video game effects. People completed a 10-item measure of pathological video game use developed to be consistent with DSM-IV criteria for pathological gambling (Gentile, 2009). Results revealed that adults with ASD ($M = 2.46 \pm 1.77$) exhibited more symptoms of pathological game use scores than TD adults (1.20 ± 1.55), with a large (Cohen's $d = 0.84$) effect size. Evidence for this group difference remained even after modeling the average amount of time spent playing video games per day and the percentage of free time spent playing video games.

With regard to children-related variables, MacMullin et al. (2016) investigated the impact of electronic use in individuals with ASD compared to TD peers. In this study, the authors enrolled 172 parents of TD individuals and 139 parents of individuals with ASD. PVG use was measured by replacing "Internet" with "video game" in the CIUS (it is based on the DSM-IV criteria for substance addiction and pathological gambling). In line with their initial assumption, the authors found that individuals with ASD ($M = 2.50 \pm 1.04$) showed higher levels of problematic video gaming compared to individuals without ASD ($M = 1.81 \pm 0.74$). The effect size value was calculated for sex differences between and within groups and then the values will be presented in a later sectionIn a third study, Mazurek and Engelhardt (2013a) aimed to investigate video game use in boys with ASD compared with those with ADHD or TD. PVG use was assessed by using a modified version of the PVGT. Using Bonferroni post-hoc analysis, they showed that ASD ($M = 41.2 \pm 12.7$) and ADHD ($M = 37.7 \pm 9.2$) groups had higher ($p = .001$) PVGT scores than the TD group ($M = 29.6 \pm 7.1$), with small (partial $\eta^2 = 0.107$) effect size. However, the ASD and ADHD groups did not differ from each other. In another study with 169 children with ASD, the same authors (Mazurek and Engelhardt, 2013b) found average scores of 39.9 ($\pm$ 11.6) using the PVGT. A recent cross-sectional study (Paulus et al., 2020) examined the levels of GD symptoms in children and adolescents with ASD and TD peers. GD symptoms (online and offline gaming) were assessed with a parent questionnaire specifically compiled for this study. To assess the degree of GD symptoms, 16 items tapped symptom criteria of the internet gaming disorder (DSM-5), with supplementary items on sleeping and eating behavior. As hypothesized, ASD boys ($M = 0.71 \pm 0.62$) showed comparably higher rates of GD symptoms than control boys ($M = 0.38 \pm 0.30$), with a medium (Cohen's $d = 0.62$) effect size, suggesting that young boys with ASD seem to be an especially vulnerable subpopulation for GD. However, it is important to note that no cut-off value was set to determine pathological cases of gaming disorder. Thus, higher scores on a video-gaming measure do not necessarily translate into clinical levels of problematic use of video games. Finally, in large population study (Mazurek & Wenstrup, 2013), parents completed measures assessing PVG use (a modified version of the PVGT) in children and their TD siblings. Children with ASD demonstrated significantly greater levels of PVG use than TD children. Also in this study, the effect size value was calculated for sex differences between and within groups

3.5. Video game use

Eleven out of the 12 eligible studies identified for review reported how people with ASD use video game in terms of frequency and time (Table 3).

Two studies on adolescents with ASD indicated that they spent an average of 2.4 h per day playing video games (Kuo, Orsmond, Coster, & Cohn, 2014; Mazurek & Engelhardt, 2013b). Another study with 169 boys with ASD suggested that adolescents with in-room access to a computer spent more hours playing video games per day (average of 3.2 h) than children without in-room access to a computer (average of 2.1 h) (Engelhardt & Mazurek, 2014). Furthermore, Finke et al. (2015) examined parental attitudes regarding

Table 4
Description of PVG findings in people with ASD.

Authors, year of publication	PVG use (mean score ± sd); effect size	Video game use (frequency and/or amount of time)	Internal factors	External factors	Interrelationship
Mazurek et al. (2012)	N/A	41.4% (ASD), 31.9% (SL) 31.5% (LD), 24.5% (MR); $p < .01$	N/A	N/A	Computer in the home ($p < .001$), Functional cognitive skills ($p < .001$) → video game use
Engelhardt et al. (2013)	N/A	2.1 h per day (ASD), 1.8 h per day (ADHD), 1.2 h per day (TD); playing video games: ASD > TD, $p = .004$	N/A	hrs sleeping per nights: 8.3 ± 1.1 within room video game < without in-room video game 8.8 ± 1.0, $P = .002$;	hrs spent playing video games per day ↘ hrs spent sleeping per night ($p = .0001$); ASD group: in-room access ⇉ daily video game hours ($P < .0001$) ⇉ less sleep after ($P < .0001$); indirect effect: from 0.42 to 1.50
Mazurek and Wenstrup (2013)	ASD (36.95 ± 4.03), TD (30.3 ± 7.7)	ASD-playing video games: 2.0 h per weekday (SD = 1.6), 3.1 h per weekend day (SD = 2.3) 2.4 h per day or 16.8 h per week (ASD), 1.6 h per day or 11.2 h per week (siblings)	male PVGT scores: 38.9 ± 11.6 (ASD) > 33.7 ± 9.8 (TD), d = 0.65; female PVGT scores: 33.2 ± 7.6 (ASD) > 27.0 ± 7.9 (TD), d = 0.81; time playing video games: male ASD > male TD, $p < .001$; female ASD > male TD, $p < .001$;	Alone: 47.9% boys with ASD, 61.3% girls with ASD, with others: 15% boys with ASD, 6.5% of girls with ASD	N/A
Mazurek and Engelhardt (2013a)	ASD (41.2 ± 12.7), ADHD (37.7 ± 9.2), TD (29.6 ± 7.1); PVGT score: ASD, ADHD > TD; $\eta^2p = 0.107$	2.1 h per day (ASD), 1.7 h per day (ADHD), 1.2 h per (TD);time playing: ASD > TD, $p = .01$	N/A	#top 4 games: Action 30.4% (ASD), 38.6% (ADHD), 17.1% (TD); Platform 21.4% (ASD), 25.0% (ADHD), 9.8% (TD), Role-playing 16.1% (ASD), 13.6% (ADHD), 4.9% (TD); Shooter 14.3% (ASD), 34.1% (ADHD), 43.9% (TD); In-room access: 42.9% (ASD), 43.2% (ADHD), 12.2% (TD)	PVGT score ↗ daily video game hrs ($r = 0.36$, $P = .008$), inattention ($r = 0.48$, $P < .001$), and hyperactivity ($r = 0.38$, $P = .004$); daily video game hrs ($b = .29$, $t = 2.6$, $P = .01$), roleplaying genre ($b = .25$, $t = 2.2$, $P = .03$), and inattention ($b = .43$, $t = 2.8$, $P = .01$) → PVGT score
Mazurek and Engelhardt (2013b)	39.9 ± 11.6	2.4 h per day	daily video game use ↗ age, $p = .003$; daily video game use ↗ PVGTscores, $p < .001$).	#1game: Action 15.7, Platform 14.3, Shooter 12.9	PVGT score ↗ inattentive symptoms ($p < .001$), oppositional/defiant symptoms ($p < .001$); PVGT score ($p < .001$) → inattention; PVGT score ($p < .001$), Role-Playing genre ($p = .039$) → oppositional behavior
Kuo et al. (2014)	N/A	2.4 h per day; 78%	68% males with ASD, 11% females with ASD ($p = .034$)	59 (65%) Alone, 1 (1%) Mother, 2 (2%) Father, 13 (14%) Sibling(s), 22 (24%) Peer(s); 46% Action games, 13% role-playng, 10% simulation game, 7% sport, 6% strategy games	N/A
Engelhardt and Mazurek (2014)	N/A	3.2 h per day with in-room access vs 2.1 h per day without an in-room access ($p < .01$)	N/A	32% in-room access, 3 h per day	video game access → oppositional behavior ($p = .01$); video game access × parental rule → oppositional behavior ($p = .03$); video game access × rules on time → oppositional behavior ($p = .02$); parental rule □ video game access × oppositional behavior
Kuo et al. (2015)	N/A	2.4 h per day (ASD), 1.5 h per day (Siblings), n.s.	N/A	parent' social mediation ↗ teen's internalizing problems ($p < 0.05$); parent' Restrictive mediation ↗ teen's Externalizing problems ($p < 0.01$)	N/A
Finke et al. (2015)	N/A	12.24 h per week, 5.99 h days per week	4.55 ± 1.46 (milde ASD symptom), 6.09 ± 1.45 (moderate ASD symptom); n.s.	Mario game (16%), LEGO game (8%), Angry Birds (8%), Pokemon (7.5%), Minecraft (4%)	parents' attitudes about the video game play ↗ behavioral beliefs ($p < .001$)
MacMullin et al. (2016)	ASD (2.50 ± 1.04), TD (1.81	2.87 h per day (ASD), 2.61 h per day (TD)	problematic and compulsive problems: 2.17 ± 0.95	N/A	N/A

(*continued on next page*)

Table 4 (*continued*)

Authors, year of publication	PVG use (mean score ± sd); effect size	Video game use (frequency and/or amount of time)	Internal factors	External factors	Interrelationship
	± 0.74); η^2p = 0.12		males, 1.74 ± 0.79 females; η^2p = 0.02; Frequency in the last month: 5.74 ± 1.12 males, 5.07 ± 1.25 females; Duration on an average day: 2.88 ± 0.97 males, 2.40 ± 0.76 females		
Engelhardt et al. (2017)	ASD (2.46 ± 1.77), TD adults (1.20 ± 1.55); d = 0.84	ASD (2.49 h per Weekday, 3.57 h per Weekend), TD (0.83 h per Weekday, 1.56 h per Weekend).	N/A	N/A	ASD group: free time spent ↗ PGU symptom; diagnostic group (b = .22), percent of free time spent playing video games (b = .01) → PGU symptom
Paulus et al. (2020)	ASD (0.71 ± 0.62), TD (0.38 ± 0.30); d = 0.62	85 ± 11.4 min per day (ASD), 50.1 ± 8.1 min per day (TD); p = .008	N/A	Alone: 84% ASD, 66% TD; with friends: 24% ASD, 48% TD; offline: 65% (ASD), 65% (TD); online: 11% (AS)D, 24% (TD); home video-games access: 69.4% (ASD), 54.8% (TD); Handheld conseole access: 54.8% (ASD), 38.7 (%)	N/A

Groups: Autism Spectrum Disorders (ASD), Attention deficit hyperactivity disorder (ADHD), Speech/language impairment (SL), Learning disability (LD), intellectual disabilities (ID), typically developing (TD), Gaming Disorder (GD).
Analyses: ↗ correlation, → regression analysis, ⇉ mediation analyses, □ moderation analyses.
Other: not available (n/a); Problematic video-game (PVG), Pathological video-game (PVU), not significant (n.s.); Cohen's d effect size (d), effect size partial eta squared (η^2p).

engagement with video games by their children with ASD. They surveyed parents of 152 children with ASD online and found that children with ASD frequently play video games, anywhere from 1 to 7 days per week, with an average of 5.99 days per week. The number of hours spent playing video games each week was variable. The average reported by the parents was 12.24 h (SD = 9.66). Five out of the eligible studies compared the frequency and amount of time spent playing video games between individuals with and without ASD. A cross-sectional study (Engelhardt et al., 2017) reported the number of hours a day (during the week and the weekend) spent playing video games by adults with ASD and TD people over the past year. Results showed that adults with ASD spent more hours daily playing video games and more of their free time playing video games (Weekday: 2.49 h; Weekend: 3.57 h) than TD adults (Weekday: 0.83 h; Weekend: 1.56 h). MacMullin et al. (2016) asked parents of children with or without ASD whether their child knew how to use a number of electronic devices and electronic activities (i.e. play video games on a computer, on a console, on a portable gaming system). No significant differences were found in the frequency (in the last month) and duration (on an average day) in video game use between individuals with ASD and without ASD (MacMullin, Lunsky, & Weiss, 2016). A recent study (Paulus et al., 2020) showed that the mean daily video gaming time of ASD boys (M = 85 ± 11.4 min) was significantly higher (p = .008) than that of controls (M = 50.1 ± 8.1 min). However, there was no significant difference in the frequency of gaming, suggesting that boys with ASD do not necessarily play more often. Yet if they do play, they do so for longer times than their peers. Comparative studies on children with ASD and TD siblings have reported contrasting findings. Kuo et al. (2015) showed no statistically significant differences between groups, while Mazurek and Wenstrup (2013) revealed that children with ASD were reported to spend a large amount of time using screen-based media. Parents estimated that their children with ASD play video games for 2.4 h per day or 16.8 h per week, whereas their siblings engaged with video games for approximately 1.6 h per day or 11.2 h per week.

Another group of studies compared video game use in children with ASD, children with other neurodevelopmental conditions, and TD children. Two studies (Engelhardt et al., 2013; Mazurek & Engelhardt, 2013a) revealed that boys with ASD spent more time playing video games than boys with TD (004) with a large effect size, whereas boys with ADHD did not differ significantly from either group. Mazurek et al. (2012) examined screen-based media use in a large nationally representative sample of youths with ASD compared with children with SL, LD and MR. Nearly half (41.4%) of youths with ASD spent most of their free time playing video games. This rate was significantly higher (p < .01) than among children with SL (31.9%), LD (31.5%), MR (24.5%), suggesting that youths with ASD are at significantly greater risk of high use of video game than youths without ASD.

3.6. Internal factors

Among internal factors, studies considered sex, ASD symptom severity and age (Table 3).

Some studies have compared male and female participants with ASD to understand if and how video game use differs by sex in individuals with ASD but provided inconsistent results. Kuo et al. (2014) reported that more males with ASD than females with ASD played video action games (53% vs 12%, p = .002) and sports or competitive games (24% vs 0%, p = .023). MacMullin et al. found a significant sex effect for video game use, with males spending significantly more time, in term of frequency, playing video games (M =

5.74 ± 1.12) than females (M = 5.07 ± 1.25), with no main effect for diagnosis (MacMullin et al., 2016). Similarly, males were found to spend more time playing video games (*M* = 2.88; *SD* = 0.97) than females (*M* = 2.40, *SD* = 0.76), in term of electronics use on an average day. None of the diagnosis × sex interactions were significant for the duration of electronics use on an average day. Furthermore, males had higher levels of problematic video game use (M = 2.17, SD = 0.95) compared to females (M = 1.74, SD = 0.79), with a very small ($\eta^2p = 0.02$) effect size. Mazurek and Wenstrup (2013) found a significant effect of diagnosis for video game use. In term of frequency, both boys and girls with ASD spent significantly more time playing video games than TD children, with effect sizes ranging from medium (boys) to large (girls). Regarding PVG play, both boys (M = 38.9 ± 11.6) and girls (M = 33.2 ± 7.6) with ASD demonstrated significantly higher PVGT scores than TD peers (M = 33.7 ± 9.8; M = 27.0 ± 7.9, respectively),with medium (Cohen's d = 0.65) and large (Cohen's d = 0.81) effect sizes, respectively. Furthermore, boys with ASD obtained significantly higher mean scores on 11 out of 19 items compared to TD boys; and girls with ASD obtained significantly higher mean scores on 9 out of 19 items compared to TD girls.

Another individual characteristic emerging from the included studies is the impact of ASD symptom severity on how people with ASD use video games. Mazurek et al. (2012) indicated that level of ASD-specific impairment (e.g., difficulties with either social interactions or communication) did not differentiate between those who spent most of their time playing video games and those who did not. Similarly, another study (Finke, Hickerson, & McLaughlin, 2015) found that severity of ASD symptoms did not affect the quantity of engagement with video games in terms of total number of hours or number of days per week played. Further, parental support and positive perception of engagement with video games did not vary substantially based on the severity of their child's ASD symptoms, independent of the severity whether their child was reported to experience mild or moderate forms of ASD.

Only a few studies have included age as a risk or protective factor for PVG use. MacMullin's study showed no significant interactions and no main effects for age at which individuals began using electronic devices, video games, Internet, or general computing activities in children and adolescents with ASD (MacMullin et al., 2016). Further, age could increase the risk for sleep problems in both ASD (effect size = 0.16) and TD (effect size = 0.46) children (Engelhardt et al., 2013), while it does not seem to predict inattention and oppositional defiant symptoms associated with problematic game use (Mazurek & Engelhardt, 2013b).

3.7. External factors

External factors including social aspects, types or genres of video games, access to video game systems and parent–child relationships may increase the risk of PVG use in people with ASD.

The studies reported in this review highlight the importance of social aspects of video gaming (playing in multiplayer mode) for individuals with ASD. In a sample of 91 adolescents with ASD, more than half (65%) played video games alone, and about one-fourth (24%) with peers (Kuo et al., 2014). Peers were companions with whom adolescents most frequently used instant messaging programs, and either sent or received e-mails. In larger populations of children with ASD (N = 202), approximately half of the boys (47.9%) and over half of the girls with ASD (61.3%) never played video games with other people, and only 15% of the boys and 6.5% of the girls with ASD were reported to play video games with others at least once a week (Mazurek & Wenstrup, 2013). The great majority of children with ASD (76% of the boys and 90.3% of the girls) never played online multiplayer games. Boys with ASD were significantly more likely than TD boys to never play video games with other people (47.9% vs. 21.6%) and were significantly more likely to never play online in multiplayer mode (76.0 vs. 39.8%). In contrast, girls with ASD were equally likely to never play video games with others, either in person or online as compared to girls without ASD. Paulus et al. (2020) suggested that individuals with ASD prefer to play alone rather than together with others and to play less frequently in multiplayer mode. They found that the 84% of ASD boys usually played by themselves vs only 66% of TD children. ASD boys played less frequently with parents, siblings, and friends than the control group. The biggest difference regarded playing with friends (ASD boys: 24%, TD: 48%). ASD boys (n = 54, mean rank = 38.67, Mdn = 0.0) were also less likely to play video games in multiplayer mode than the control group (n = 29, mean rank = 46.67, Mdn = 0.0). Furthermore, ASD boys were 4.29 times more likely (OR) to play video games on their own.

Another important aspect emerging from these studies is the choice of types or genres of video games. Video games are usually assigned to special categories, or genres, based on the way players interact with the game. A study with 12- to 18-year-olds (Kuo et al., 2014) showed that 46% of boys with ASD preferred to play action games, while simulation games and role-playing games made about 10%–20% of reported games. In addition, adolescents with ASD less frequently played classic games (including board games, card games, puzzles, gambling, word games, and game shows), racing games, and adventure games, with each of them accounting for less than 5% of reported games. These results were in agreement with Mazurek and Engelhardt (2013a)'s who also found that the action category was the most frequently reported as first choice in a sample of 169 boys (ages 8–18) with ASD. Furthermore, some studies have shown differences in the choice of genres between children with ASD and TD children. Using Post-hoc bivariate Fisher exact tests, Mazurek and Engelhardt (2013a) showed that TD children preferred to play shooter games compared with the ASD group. In an open-ended format (Paulus et al., 2020) parents reported that Minecraft (adventure and action) was the favorite video game for boys with ASD (18.5%) and without ASD (20%), followed by racing games (9.3%). In this study, about two-thirds of the ASD (65.5%) and the TD (65.5%) boys usually played video games offline, while about one-tenth (11%) of the ASD and one-quarter (24%) of the TD boys reported using video games usually online. However, there seemed to be no difference in the types of video games played (Finke et al., 2015) between children with mild and moderate forms of ASD, and the top five games preferred were some variation of a Mario game (16%), some variation of a LEGO game (8%), Angry Birds (8%), Pokemon (7.5%), or Minecraft (4%). Other games reported regularly (7–10 occasions each) were Call of Duty, Plants vs Zombies, Skylanders, Sonic, and Wii Sports.

Having easy access to video game systems in their homes or bedrooms may be a particularly important aspect of the household media environment for individuals with ASD. Engelhardt and Mazurek (2014) documented that nearly 32% of their sample had

in-room access to a video game system, and 25% of the sample had in-room access to a computer. Moreover, children with in-room access to a video game system spent more time playing video games every day (M = 3.0; SD = 1.9) than children without an in-room system (M = 2.1; SD = 1.5). Similarly, another study showed that, in the ASD group, in-room access to video games (ie, access to a computer or dedicated game system) was associated with daily video game hours ($P < .0001$), and daily video game hours were associated with less sleep after accounting for the association between in-room game access and sleep (Engelhardt et al., 2013). Mazurek and Engelhardt (2013a) showed that more individuals in both ASD and ADHD groups had in-room video game systems compared with the TD group, with a medium effect size, whereas the ASD and ADHD groups did not differ. A study with 62 children with ASD showed (Paulus et al., 2020) that more than two thirds of the ASD boys had access to a computer or a home video game console, and about half of them had access to a hand-held video game console, a tablet computer, and a smartphone. However, no significant differences were found in access to technical devices between children with ASD and TD children.

Of the twelve eligible studies, three focused on the association between video game use and parent–child relationships. Two studies examined strategies that parents use to control, supervise, or interpret the use of video games by their children. In a longitudinal study (two time points, approximately 1 year apart), Kuo et al. (2015) found that, parents most frequently used restrictive mediation and less frequently used social mediation for adolescents with ASD and their siblings but more frequently applied restrictive and instructive strategies for video gaming. About half of the parents (52%) reported feeling stressed having to manage video game playing variables such as compulsion and obsession with videogaming, unproductive use of time due to prolonged gaming, and negative emotions (e.g. moody, irritable) when asked to stop playing. Further, an association was found between parents playing video games with adolescents (social mediation) ($p < .05$) and less internalizing behavior problems in these adolescents. By contrast, being a younger adolescent with ASD and having more externalizing behavior problems was associated ($p < .01$). with more restrictive mediation. Engelhardt and Mazurek (2014) found that a large number of parents (87%) regulated hours of video game play and days as well as age-specific ratings of games. Furthermore, unlimited access to video games was highly correlated with increased oppositional behavior (e.g., temper tantrums, questioning authority), particularly in children with ASD who had no parent-reported rules regulating their video game use. Finke et al. (2015) examined parental attitudes regarding engagement with video games by their children and whether attitudes vary based on ASD symptom severity. They showed that the correlation between behavioral belief and parents' attitudes about video game play of their children was statistically significant ($p < .001$). Results indicated that parents with more positive beliefs about the outcomes of their child's video game play are more likely to have positive attitudes about their child's video game play. In other words, parents of children with ASD generally believed that positive behavioral outcomes were associated with video gaming in areas such as social skills, fine motor skills, language skills, reading and writing, and critical thinking. These findings appear to indicate that parents would be supportive of the use of video games in educational and therapeutic contexts.

3.8. Analysis of the interrelationship between video game use and ASD

Five studies used multivariate logistic regression models to identify potential predictors of PVG use in individuals with ASD. Two studies showed that game features such as in-room access to a video game console, average time spent playing video games per day and/or amount of free time spent playing video games were significant predictors of PVG use in both children and adults with ASD (Engelhardt & Mazurek, 2014; Engelhardt et al., 2017). More specifically, in-room access to a video game console ($p = .01$) also predicted oppositional behavior while controlling for in-room access to other media devices (computer and television) and relevant variables (e.g. average number of video game hours played per day). These findings suggested that the association between in-room access to a video game console and oppositional behavior in children with ASD seems particularly close when parents reported no rules on their child's video game use. In a sample of 910 adolescents with ASD (aged 13–17 years), Mazurek et al. (2012) also indicated that access to technology at home ($p < .05$) and higher functional cognitive skills ($p < .001$) were significant predictors of PVG use. By contrast, family income or other demographic factors did not significantly predict video game use among adolescents with ASD. Thus, it appears that use of video games is highly prevalent among youths with ASD and is largely independent of individual or socio-demographic factors. Finally, in two studies carried out in 2013, Mazurek & Engelhardt examined the associations between video game play variables and behavior problems in children and adolescents with ASD. In the first study (Mazurek & Engelhardt, 2013a), daily video game hours ($b = .29$, $t = 2.6$, $p = .01$), role-playing genre ($b = .25$, $t = 2.2$, $p = .03$), and inattention ($b = .43$, $t = 2.8$, $p = .01$) were significant predictors of PVGT score, whereas hyperactivity was not a significant predictor ($p = .54$). In the second study (Mazurek & Engelhardt, 2013b), a significant main effect was observed for PVGT score ($p < .001$). With regard to the model predicting oppositional behavior, results showed significant main effects of both PVGT score ($p < .001$) and Role-Playing genre ($p = .039$). Interestingly, violent video game use did not emerge as a significant predictor of either oppositional behavior or inattention in either bivariate or multivariate models.

Only one study evaluated potential mediators of the association between ASD and problematic or excessive gaming. Engelhardt et al. (2013) speculated that in-room access to screen-based media would have an indirect effect on total sleep time through average media hours. Findings suggested that the association between media exposure and sleep was more marked in boys with ASD than boys with ADHD or TD and in-room access to screen-based media and time spent playing video games may increase the risk for sleep problems (the 95% confidence interval for the magnitude of this indirect effect ranged from 0.42 to 1.50, suggesting significant mediation) in individuals with ASD.

Another study (Engelhardt & Mazurek, 2014) investigated parental rules as a potential moderator of the relationship between in-room access to video games and problem behavior. However, the authors found no evidence of a simple association between parental video game rules and oppositional behaviors in children with ASD, although they did find that parental rules moderated the relationship between in-room game access and oppositional behaviors.

4. Discussion

The aim of this review was to analyze and describe the literature on co-occurrence of PVG use and ASD in children, adolescents and adults. The quality of the evidence for this outcome was moderate owing to the paucity of high-quality studies and the small number of studies included (only twelve). Findings showed that use of video games in individuals with ASD is an area of ambiguity comprising inconsistencies in terminology used to describe pathological video game use and multiple assessment instruments, ranging from ad-hoc questionnaires to adapted psychometric tools. Studies included in this review primarily focused on how people with ASD use video game, in terms of frequency and amount of time, while some studies examined individual characteristics (i.e. sex, age), contextual factors (i.e. family and peer-related factors) and factors related to game variables (i.e. game genre). Of note, few studies focused on consequences (i.e. psychosocial well-being and cognitive or behavioral deficits) of excessive video gaming in people with ASD. This highlights that more longitudinal studies are required to achieve a better understanding of problematic use of video games in children, adolescents and young adults in ASD.

4.1. Problematic video-game use

Most studies agree that people with ASD showed significantly greater levels of PVG use than TD people, suggesting that individuals with ASD seem to be at greater risk for pathological video-game use than children or youths without ASD. These findings have been replicated across different countries, in different age groups (children, adolescents and young adults) and with different assessment instruments. However, these data must be interpreted with caution because all reviewed studies used gaming as a continuous variable. None of the reviewed studies have established empirical or clinical cut-off points (i.e. 5 or more addiction symptoms) with the aim to discriminating gaming addicts from game enthusiasts. Currently, a large debate exists on whether problematic gaming should be considered as a new disorder in the literature. The major concerns are that the current operationalization of PV use is too heavily based on the criteria for substance use and gambling disorder, and at present there is a lack of consensus on the symptomatology of pathological video game use and how to assess it (Griffiths, Kuss, Lopez-Fernandez, & Pontes, 2017; Aarseth et al., 2017). However, quantitative findings indicate a meaningful difference in PVG use in individuals with and without ASD (Engelhardt et al., 2017; MacMullin et al., 2016; Mazurek & Wenstrup, 2013; Paulus et al., 2020). Hence, dismissing the clinical significance and the individual impact that excessive gaming can have on the overall health of people with ASD may inevitably lead to a number of detrimental negative outcomes. It is therefore important to acknowledge that excessive and detrimental use of video games may be an important clinical consideration for population with ASD. Individuals with ASD are at risk for social isolation which in turn can lead to a greater risk for excessive use of video games (Kuo et al., 2014; Mazurek & Wenstrup, 2013; Paulus et al., 2020). Further, people with ASD are probably more prone to problematic electronics use because of other characteristics associated with the disorder. For example, highly restricted interests may manifest as preoccupations with video games or compulsive patterns of game play (Engelhardt et al., 2017). However, it may be difficult to separate PVG use from restricted interests and repetitive behaviors, which are common in individuals diagnosed with ASD. This distinction has important implications for treatment. Paulus et al. (2020) suggested that, if an individual with ASD has developed a GD, it should be treated as a comorbid diagnosis. If the gaming activity is a restricted interest, it might be useful to include it in the therapy of the autistic core symptoms. Unfortunately, there is no tool to date that provides an excellent distinction between restricted interests/repetitive behaviors and PVG use in ASD. Furthermore, individuals with ASD differed from their TD siblings (control group) in terms of PVG use scores but did not differ from children and adolescents with ADHD. Deficits in impulse control and response inhibition are associated with both ASD or ADHD (Xiao et al., 2012) and seem to be an obvious overlap between these conditions (Craig et al., 2015). A recent review (Şalvarlı & Griffiths, 2019) of 33 eligible empirical studies showed that poor impulse control and high-level impulsivity are also associated with IGD. Further, neuroimaging studies revealed that distortion in the system of cognitive control causes impulsivity (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011) and decreased executive control can be critical in the development of addictive behaviors (Brand et al., 2019). Hence, more research is needed to examine the association between these executive functioning deficits and PVG use for individuals with ASD.

Furthermore, the majority of studies showed that individuals with ASD spent over 2 h playing video games per day, with a weekly average ranging from 12.24 to 16.8 h. This exceeded the American Academy of Pediatrics' recommendation for combined screen-based media exposure (Council On & Media, 2016). The time spent playing video games is greater than that of TD children or that of individuals with other neurodevelopmental disorders (Mazurek & Engelhardt, 2013a; Mazurek et al., 2012), whereas whereas it did not differsignificantly from children with ADHD. Adolescents with in-room access to a computer spent more hours playing video games per day than children without in-room access to a computer. Children with ASD also play more video games than their TD siblings and spend far more time playing video games than doing other extracurricular activities (Mazurek & Wenstrup, 2013). Excessive play may be deleterious; studies indicate a negative correlation between time spent playing video games and sleep, particularly if played in a child's bedroom or before bed, and poorer behavioral functioning (Engelhardt et al., 2013). These findings are consistent with anecdotal reports from parents and clinicians that many individuals with ASD exhibit patterns of excessive video game play. However, two studies (MacMullin et al., 2016; Paulus et al., 2020) found no significant difference in the frequency of gaming between ASD and TD children, suggesting that boys with ASD do not necessarily play more often. Yet, if they do play, they continue to do so for longer times than their peers.

4.2. Internal factors

Some studies reviewed here assessed internal factors associated with PVG use in individuals with ASD. Three studies looked at sex

differences and PVG use comparing ASD and TD populations. Only one study indicated that children with ASD of either sex are more likely to demonstrate problematic patterns of play than TD children (Mazurek & Wenstrup, 2013). Other previous studies found males to be at significantly higher risk of developing PVG use, with no main effect for diagnosis. More specifically, boys with or without ASD showed higher rates of PVG use than girls with or without ASD. Males also spent significantly more time playing video games than females, with effect sizes ranging from medium (among boys) to large (among girls). These results are in agreement with the sex differences observed in the general population (Cudo, Toroj, Misiuro, & Griffiths, 2020), suggesting that boys with ASD are particularly vulnerable to PVG use. These findings may partly be explained by sex differences in activation and connectivity of brain regions associated with the mesocorticolimbic reward system (Hoeft, Watson, Kesler, Bettinger, & Reiss, 2008). Hence, the higher risk of gaming addiction for males with ASD could be related to neuronal differences (Alaerts, Swinnen, & Wenderoth, 2016; Zhang et al., 2020). However, findings in relation to factors mediating sex-related differences on PVG behavior appear limited and should be a focus for the future.

Most studies cited in our review investigated pre-adolescents and adolescents with ASD. No studies have analyzed PVG use in pre-school children yet, and only one article included data on adults with ASD. This discrepancy could be attributed to the fact that the data from the general population focused primarily on pre- and young adolescents. This may be related to a greater technology affinity of 'digital natives' and the developmental tasks typical of this age. However, a recent study reported that this area is particularly relevant also to emerging adults (18–29 years) because they access the Internet or console more than any other age group (Yau, Crowley, Mayes, & Potenza, 2012) and are therefore more at risk of developing video games and internet addiction. Importantly, video or digital game use should not go unnoticed in pre-schoolers with ASD because this could lead to PVG use later in life.

Contrary to expectations, the level of ASD-specific impairment (e.g., difficulties with either social interactions or communication) did not differentiate between individuals who spent most of their time playing video games and those who did not. It can therefore be assumed that use of video games is highly prevalent among youths with ASD and is largely independent of individual factors. It is also interesting to note that some studies on the general population showed an association between autistic traits and internet gaming addiction (IGA). Finkenauer, Pollmann, Begeer, and Kerkhof (2012) reported that people with more autistic traits were more prone to compulsive Internet use. Similarly, Liu et al. (2017) showed that autistic traits were related to decreased emotion regulation which in turn was related to increased IGA. Furthermore, autistic traits are related to other negative outcomes such as emotion dysregulation (Conner et al., 2020) and suicidal risk in individuals with problematic internet use (Dell'Osso et al., 2019). Hence, future longitudinal studies should further evaluate the mechanisms underlying the dangerous association between gaming addiction, emotion dysregulation and autistic traits via concurrent consideration of the phenotypic heterogeneity level of functioning and other clinical characteristics.

4.3. External factors

Among external factors, social aspects, types or genres of video games, access to video game systems and parent–child relationships may increase the risk of developing PVG use among people with ASD.

Although video game play is assumed to be largely solitary, most gamers play with a friend, and millions of people worldwide participate in massive virtual worlds through video games (Cummings & Vandewater, 2007). For most, this is a positive experience, allowing them to communicate with others even when they are unable to physically be with them. However, three studies reviewed here suggest that the great majority of males and females with ASD never played video games with other people and were significantly more likely to never play online in multiplayer mode (Kuo et al., 2014; Mazurek & Wenstrup, 2013; Paulus et al., 2020). These patterns indicate that social difficulties in real-life associated with ASD seem to be reflected in the gaming situation. Individuals with ASD are at risk for poor social outcomes, including reduced engagement in social and community activities, education, and employment. Previous studies revealed that people with ASD are rejected by peers up to four times more than TD people (Little, 2002), likely as a result of their poor social functioning, difficulties to initiate interactions with others, and lack of close friendships, which are known to buffer individuals from the effects of social stressors. In addition, individuals with ASD have trouble interpreting complex social interactions and the intentions of others more generally, and they are less able to make quick judgments in social contexts, which might further undermine their social interactions with peers (Masten et al., 2011). It is therefore possible that social difficulties may be associated with rejection and social isolation from peers which cause youths with ASD to play video games alone. Further, whilst several social aspects play a crucial role when TD children play video games (Olson, 2010), ASD boys are apparently less able to exploit opportunities for social interaction offered by video games. Studies from the general population found that online social interaction strengthens meaningful feelings and self-regulation and reduces negative feelings such as loneliness and boredom (Haagsma, Pieterse, Peters, & King, 2013). Indeed, video games can be a safe place to experiment with social interaction. In addition, the presence of a shared activity facilitates the development and maintenance of social relationships as well as further socially accommodate its users, as social communication can become intertwined with the activity itself, reducing the pressure to maintain and guide direct socialization. On the contrary, Valkenburg and Peter (2008) found that adolescents who were lonely, introverted or socially anxious were less likely to use the internet for social communication. Hence, future research should examine whether and how social video game use changes over time, particularly among people with ASD.

Structural characteristics of specific video game genres will promote a PVG use among people with ASD (Mazurek & Engelhardt, 2013a). The most frequent favorite video game genres were Role-Playing and Action-Adventure, followed by classic games, racing games, and sports games (Paulus et al., 2020). Previous studies found that Role-Playing games are associated with problematic game use in individuals without ASD (Smyth, 2007). Given their tendency to engage in restricted and repetitive patterns of activity, children or adults with ASD may be at particular risk for developing problematic game play patterns, and Role-playing games (Minecraft,

Pokemon, and Mario Bros) can be especially difficult for children with ASD to disengage from, given their particular game-design features (i.e. avatars, finding rare in-game items, and watching videogame cut-scenes).

Parents of children or adolescents with ASD are well aware of these behaviors. Parents frequently have mixed feelings about the game and their children's level of engagement with it. First, parents report that children or adolescents with ASD can become so focused on video game play that they refuse to do any other activity. There are studies that support these observations that children with ASD tend to become overly engaged in a video game play, can become inattentive as a result of extended game play, or develop obsessions (particularly with role-playing games). For this reason, parents more frequently applied restrictive and instructive strategies for video-gaming with adolescents with ASD than their siblings (Kuo, Magill-Evans, & Zwaigenbaum, 2015). Moreover, behavior problems were associated with mediation strategies (playing together) This did not hold for ASD symptoms. On the other hand, parents of children with ASD also reported positive feelings about the social and other developmental benefits of video gaming, particularly fine motor and critical thinking abilities (Finke et al., 2015). These ambiguous results highlight that managing video game use may be stressful for parents of children with ASD. However, if guided by health care professionals, parents would be supportive of the use of video games in educational and therapeutic contexts.

Finally, easy access to video game systems could be another key factor for developing PVG use. The majority of studies showed that boys with ASD were more likely to have video game access in their rooms and then spent more time playing video games per day (Engelhardt & Mazurek, 2014; Mazurek & Engelhardt, 2013a; Paulus et al., 2020). These factors may place people with ASD at increased risk for excessive video game use, oppositional behavior and sleep problems. Specialists should routinely assess video game access habits in order to prevent possible problem behaviors.

4.4. Analysis of the interrelationship between video game use and ASD

Different approaches to identify the relationship between video game use and ASD were used in various studies. Correlation studies confirmed a link between external factors (i.e. parental strategies, game genres, social aspects) and problematic video game use among people with ASD. However, a cause-effect relationship cannot be determined. Regression, mediation and moderation analysis were used in order to provide insights on the causal relationship between internal or external factors and PVG use in ASD. Six studies have focused on identifying predictors associated with PVG use. Average time spent playing video games per day, amount of free time spent playing video games, higher functional cognitive skills, absence of parental guidance role, Role-Playing game genre, attention problems and oppositional behavior were identified as potential predictors (Mazurek et al., 2012; Engelhardt et al., 2013; Mazurek & Engelhardt, 2013a; Engelhardt et al., 2013; Engelhardt & Mazurek, 2014; Paulus et al., 2020). These potential predictors should be explored in future studies on the causes of problematic video game use in people with ASD. In addition, it seems likely that excessive players with ASD have a higher risk of sleep problems, which are possibly mediated by in-room access to screen-based media and time spent playing video games (Engelhardt et al., 2013). Perhaps the most intuitive explanations are that exposure to video games, particularly at night, intrudes on the amount of time that could be spent sleeping, or that exposure to brightly lit screens may disrupt melatonin production, which could have a particularly detrimental effect on sleep quality in children with ASD because they are already at risk for abnormally low melatonin concentrations (Hale et al., 2018) Also, it appears that parental rules are effective in reducing the amount of time their child spends playing video games. Although there is growing recognition of adolescent video gaming as a potential clinical problem, few empirical studies investigated the impact of protective parental rules. Further research should explore inconsistent parenting styles or conflictual parent–child relationships, so parents are ultimately better informed about ways to promote gaming in healthy moderation and reduce the potential risks for excessive gaming.

Overall, the majority of previous studies are cross-sectional in design and do not allow for a causal interpretation of current results. Longitudinal and experimental studies are necessary to determine predictors, mediators, and outcomes of PVG use among individuals with ASD.

4.5. Methodological problems

The studies included in the review have methodological limitations that call for caution in the interpretation and generalization of their findings.

One challenge for interpreting the existing literature is the diversity of terminological and methodological approaches used to PVG use. Given the heterogeneity of instruments designed for assessing gaming addiction and some of the criticisms previously mentioned (i.e. inconsistency in the conceptualization of gaming addiction; use of non-standardized criteria; etc.), experts in the field have now called for unification in the assessment of gaming addiction (Pontes & Griffiths, 2014). Furthermore, the majority of instruments were designed to assess video game use, but no cut-off value was set to determine pathological cases of gaming disorder. This issue is especially important as this is the only way to ascertain how robustly measures discriminate gaming addicts from game enthusiasts. A possible explanation for this might be that that the vast majority of the available measures were not validated using clinical samples.

Second, further difficulties exist including the need for strict and detailed sample characterization. Only one of all the studies reviewed investigated PVG use in adults with ASD. Studies reported in the literature therefore do not take into account the fact that the demographics of gaming have changed and that the typical gamer is no longer a male teenager but a person in his late twenties or early thirties. In addition, given the fact that video game use is gender-neutral, there is likely to be increasing feminization of gaming with increasing numbers of females not only engaging in online games, but also developing problems as a result (Griffiths, 2014). To analyze these clues, however, it must also be noted that ASD in females is often unrecognized and undiagnosed (Livingston & Happé, 2017).

Third, the results of this review highlight the paucity of research examining the impact/effect of excessive and problematic use of

video game on people with ASD. Data from the general population showed that problematic gaming may lead to several negative physical, psychosocial consequences and mental health problems affecting available time, work, education, family, partnership, friends, social life, psychosocial well-being, social competence, leisure activities, self-esteem, and loneliness (Sugaya, Shirasaka, Takahashi, & Kanda, 2019; von der Heiden et al., 2019). Further studies are needed to evaluate this in the ASD population.

4.6. Future research and recommendations

There are still many unanswered questions regarding association between PVG use and ASD.

First, research should consider if the validity of the current DSM-5 classification system of GD is applicable to people with ASD, with regard to both criteria and cut points. In addition, future psychometric studies are needed to promote the development of measures suitable to distinguish GD symptoms or PVG use from restricted interests and repetitive behaviors, which are common in people diagnosed with ASD.

Second, our review highlights the paucity of available data on the consequences of problematic gaming on people with ASD. While studies have shown that excessive video game play leads to problematic behavior in the TD population, there has been little to no research, up until this point, investigating whether video game use also leads to problematic behavior in people with ASD. Longitudinal studies and qualitative studies are needed to understand the cause-and-effect relationships between videogaming and behavior problems.

Third, there is insufficient evidence on how long PVG use takes to develop in an autism condition, how long it lasts, or whether it is continuous or intermittent during lifetime. Further research is needed to outline internal or external factors (age, ASD functioning problematic use of video game, genres of video games, parent–child relationships) that are more or less significant predictors of problematic game use in children and adolescents with ASD.

Fourth, although research has shown that people with ASD showed significantly greater levels of PVG use than TD people, the underlying mediating mechanisms has not been identified. Future studies should examine neurobiological and psychological mechanisms that mediate the relationships between ASD and video game use.

Recently, the American Academy of Pediatrics recommended that time allotted to play video game should be under 1 h per day on school days and 2 h or less on non-school days. Healthcare professionals should advise against placing video game systems in bedrooms (at all ages) and encourage parents of children or adolescents with ASD to limit the total amount of screen time, given that access and amount of time gaming tend to be risk factors for PVG use. Furthermore, autism specialists can help parents define household rules around gaming as well as develop effective mediation strategies. Studies has revealed that playing video games together (social mediation) is a powerful protective factor for children and adolescents with ASD. Further, it is essential to encourage playing with parents, siblings, friends as well as online in multiplayer mode so that individuals with ASD can practice and increase social skills. Multiplayer games provide people with ASD with an opportunity for joint attention and shared interests with their peers. They may be unaware of social cues and conventions, yet when they play massively multiplayer online games like Roblox, Minecraft, or World of Warcraft, they need to learn the social customs of the game world. Finally, for individuals with ASD who develop problematic video game use, autism specialists and other clinicians should work to best determine the best intervention strategy including psychological and/or pharmacological treatment.

5. Conclusion

To our knowledge, this is the first review to systematically analyze empirical evidence on PVG use in people with ASD. Despite the limited number of high-quality studies, results indicate that individuals with ASD may be at greater risk of PVG use than children or youths without ASD. These findings have been replicated across different countries, in different age groups (children, adolescents and young adults), and with different assessment instruments. Thus, individuals with ASD should specifically be screened for PVG use, but future psychometric studies are needed to promote the development of measures suitable for individuals with ASD, particularly in the presence of restricted interests that may complicate differential diagnosis. The studies considered in this review mainly focused on internal or external factors associated with PVG use, suggesting that sex differences, average time spent playing video games per day, amount of free time spent playing video games, absence of parental guidance role, Role-Playing game genre, and attention problems and oppositional behavior might be significant predictors of PVG use in children and adolescents with ASD. It is interesting to note that the social difficulties in real-life associated with ASD seem to be reflected in the gaming situation.

Unfortunately, conclusions of our review were limited by the population characteristics, number of studies and study design, diversity of terminological and methodological (e.g. no clinical cut-off value) approaches to PVG use. Further, the literature partly overlooked the consequences and individual effects of excessive video gaming in people with ASD. Longitudinal studies are needed to understand the short-term effects of excessive and problematic video game use that can lead to more severe long-term repercussions in people with ASD.

Declaration of Competing Interest

- that all co-authors have seen and approved the final version of the paper and accept responsibility for the data presented.
- that there is no financial or others conflict of interest that may be related to the authors.
- this work has not been submitted for publication elsewhere.

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