International Journal of Mental Health and Addiction (2022) 20:92–118
https://doi.org/10.1007/s11469-019-00126-w

ORIGINAL ARTICLE

The Association Between Internet Gaming Disorder and Impulsivity: A Systematic Review of Literature

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Published online: 23 August 2019
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Abstract
Research examining Internet Gaming Disorder (IGD) has increased substantially over the past decade. One of the risk factors for IGD includes poor impulse control. The present study comprises the first ever systematic review of studies examining the relationship between IGD and impusivity utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. A literature search was conducted via EBSCO (which included the following academic databases: Academic Search Complete, PsycARTICLES, and PsycINFO), PubMed, ScienceDirect, Web of Science, and Wiley Online Library. The inclusion criteria were (i) publication date between 2000 and 2019, (ii) being an empirical study that collected primary data, (iii) written in English and Turkish languages (the two languages spoken by the authors), (iv) published in a scholarly peer-reviewed journal, and (v) conducted an objective assessment of both IGD and impulsivity. Following these procedures, 33 eligible empirical studies remained for evaluation in the present review comprising 18,128 participants in total. Results demonstrated that despite many methodological weaknesses, 32 studies reported a positive association between impulsivity and IGD. Possible explanations for this consistent finding appear to indicate that altered neurobiological structures detected in participants with impulsivity may explain some of the relationships between impulsivity and internet gaming disorder.

Keywords Impulsivity · Videogames · Internet gaming disorder · Gaming disorder · Gaming addiction

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Playing videogames has become one of the most popular entertainment events around the world, especially since the inception of online multiplayer games featuring both collaboration and competition (Nuyens et al. 2016). Videogames are often an enjoyable way of reducing stress, socializing with friends, and spending time (Stockdale and Coyne 2018). Through playing videogames, many goals are achieved such as relaxation, competence, autonomy, and avoidance of daily concerns (Griffiths 2003; Ryan et al. 2006). Due to the "flow" status of playing games, the player gets a sense of control, loses sense of time and place, and finds playing self-rewarding (Csikszentmihalyi 1990). Greater ventral striatal presynaptic dopamine release in healthy volunteers during game-playing supports the assumption that the activity is potentially rewarding in itself (Koepp et al. 1998). After a 6-week gaming period, when the gaming cues were encountered, increased orbitofrontal and anterior cingulate activity was observed in healthy volunteers. This suggests that game-playing can be reinforcing and associated cues can become conditioned reinforcers (Han et al. 2010). For most videogame players, the activity is fun and exciting but when it harms the player's social, occupational/educational, family, and psychological functioning, it can become pathological (Gentile et al. 2011). In other words, for this small minority of individuals, they become preoccupied with playing games constantly, deprive themselves of their social life for the sake of playing, and use gaming to cope with real-world pressure, all of which can be symptoms of addiction (Gunuc 2015; Kuss and Griffiths 2012; Mai et al. 2012).

The psychological mechanisms underlying the prevention and intervention of problematic gaming needs to be understood (Hu et al. 2017). More specifically, many issues need to be clarified in order for Internet Gaming Disorder (IGD) to be considered as a formal diagnosis in the next edition of the *Diagnostic and Statistical Manual of Mental Disorders*. Such issues include risk and protective factors for IGD, comorbid patterns with IGD, structure of IGD, typical consequences of IGD, and effective approaches in overcoming IGD (Gentile et al. 2011).

Behavioral patterns such as persistent thoughts related with online gaming and continuous use of the internet to take part in games are basis of the clinical diagnosis of IGD. In extreme cases, these patterns lead to serious impairment or distress (American Psychiatric Association 2013). Consequently, IGD has been defined and conceptualized in the context of behavioral addiction (Dowling 2014; Pontes et al. 2014) and the need to determine the diagnostic criteria for the differentiating IGD from gambling and substance addictions has been emphasized by many researchers (Griffiths et al. 2016). Several modified criteria used for substance addiction have been utilized for IGD in the DSM-5. In addition to the aforementioned criteria, other criteria comprising IGD include tolerance, withdrawal, persistent use despite negative outcomes, inability to restrict internet use, disruption in psychosocial functioning, loss of interest in previous hobbies, and escapism (Yen et al. 2017).

Both positive reinforcement (i.e., receiving a reward or reaching higher levels in the videogame) and negative reinforcement (i.e., playing to avoid negative affectivity) can be factors in the development of gaming addiction (Choi et al. 2007; Yee 2006). Other risk factors for IGD include decreased social competence (Gentile et al. 2011), poor impulse control (Griffiths et al. 2012), increased time allocated to gaming (Gentile et al. 2011), sensation seeking, narcissistic personality traits (Griffiths et al. 2012), and high anxiety (Mehroof and Griffiths 2010). Furthermore, distortion in response inhibition when faced with the game-related clues has also been associated with gaming addiction. Here, attentional biases may be effective in maintaining the problem by increasing the risk of relapse (van Holst et al. 2012).

Repetitive harmful behavior and loss of control have been proposed as specific features of IGD in both the DSM-5 and ICD-11 (Király and Demetrovics 2017). A variety of executive control problems are associated with IGD, such as failure in response inhibition (Ding et al. 2014), disrupted error monitoring (Dong et al. 2013), and cognitive inflexibility (Dong et al. 2014). It is also known that high-level impulsivity is related with IGD (Cao et al. 2007). Studies evaluating neurocognitive functions have proposed that impulsivity in IGD is more pronounced compared to other behavioral addictions such as gambling disorder (Choi et al. 2014). Consequently, increased impulsivity is included in most IGD models such as Dual System Models (Bechara 2005) and the Interaction of Person-Affect-Cognition-Execution (I-PACE) Model (Brand et al. 2016). According to neuroimaging studies, distortion in the system of cognitive control causes impulsivity (Steinberg et al. 2008) and decreased executive control can be critical in the development of addictive behaviors (Brand et al. 2016). Studies have also demonstrated that during impulse control-related tasks, addicted players experience abnormal activations in frontal, insular, temporal, and parietal cortex compared to healthy controls (Dong et al. 2012). Furthermore, impulsivity is associated with depression (Granö et al. 2007; Swann et al. 2008) and indirectly causes loneliness and failures in interpersonal relationships (Savci and Aysan 2016). Thus, impulsivity can be a contributory factor in consequent emotional and social functioning (Ryu et al. 2018).

Impulsivity is accepted as multidimensional and subdivided into five dimensions encompassing negative and positive urgency (acting rashly when experiencing intense negative or positive emotions respectively), lack of premeditation (acting without considering the consequences), lack of perseverance (failure in maintaining focus on a boring or difficult task), and sensation seeking (pursuing exciting activities) (Cyders and Smith 2008). In other words, impulsivity is associated with inability to consider alternative solutions, doing the first thing that comes to mind without assessing the consequences (D'Zurilla et al. 2003), and failure in self-control when faced with reward or punishment (Stewart et al. 2004). Thus, impulsivity is recognized as a predictive factor in the development of maladaptive behaviors resulting in relief from negative emotions (Cyders and Smith 2008). Despite such research, to the present authors' knowledge, there has never been a review paper examining the relationship between impulsivity and IGD utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Consequently, the present paper synthesizes the available literature according to PRISMA guidelines.

Method

Eligibility Criteria

All studies assessing the phenomenon of IGD and impulsivity were eligible for review. The inclusion criteria were (i) publication date between 2000 and 2019, (ii) being an empirical study that collected primary data, (iii) written in English and Turkish languages (the two languages spoken by the authors), (iv) published in a scholarly peer-reviewed journal, and (v) conducted an objective assessment of both IGD and impulsivity. Studies were excluded from the review if they were (i) single-case studies, (ii) unpublished thesis and dissertation studies, and (iii) not published in a peer-reviewed journal.

Information Sources and Search

A literature search was conducted via EBSCO (which included the following academic databases: Academic Search Complete, PsycARTICLES, and PsycINFO), PubMed, ScienceDirect, Web of Science, and Wiley Online Library. Several searches in the stated electronic databases were conducted during February 2019 using the following search terms: (internet OR video OR computer) AND game OR gaming (addict* OR depend* OR disorder) AND impulsivity OR impulse control OR impuls*.

Study Selection and Data Collection Processes

After the initial literature searches that were conducted, the title and abstract of each study was screened and then potentially relevant studies were further evaluated for eligibility. The detailed information about study selection process is provided in the PRISMA flow diagram (Fig. 1). In the process of assessing risk of bias in each study, sampling bias and measurement bias were also assessed.

Results

Study Selection

A total of 1663 studies (EBSCO, $n = 581$; PubMed, $n = 286$; ScienceDirect, $n = 442$; Web of Science, $n = 301$; Wiley Online Library, $n = 53$) were identified in the initial search process.

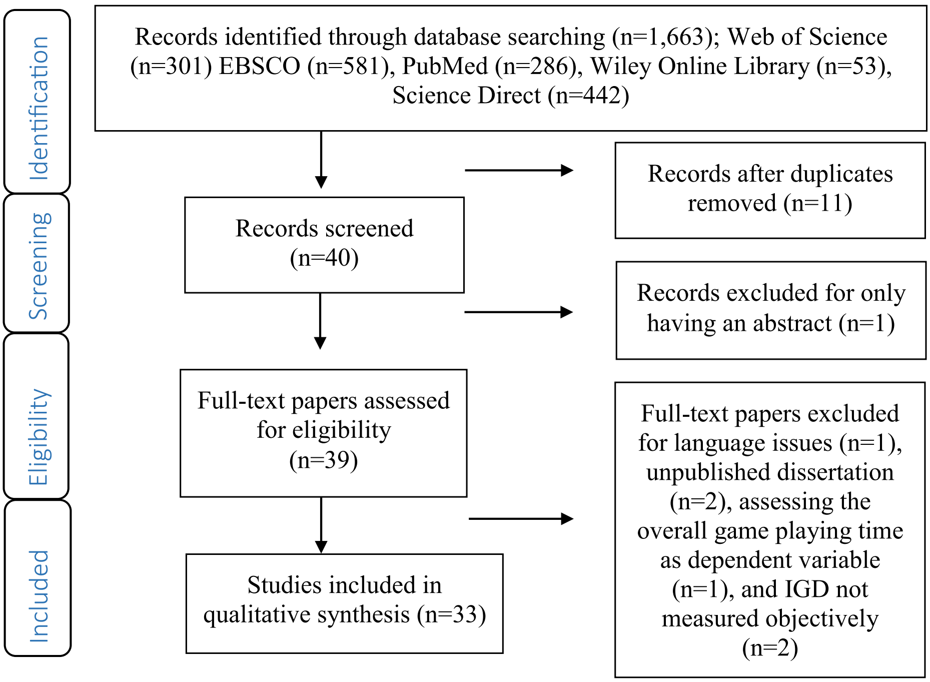

Fig. 1 PRISMA flow diagram of paper selection process used in the present study

After the title and abstract of each study was examined, 1612 studies were excluded because of unsuitability for the present review. A further 12 studies were excluded due to duplication (n = 11) or only having an abstract (n = 1). Consequently, a total of 39 studies were selected for eligibility phase. Of these, a total of six studies were excluded for language issues (n = 1), being an unpublished dissertation (n = 2), assessing the overall game playing time as dependent variable (n = 1), or not assessing IGD objectively (n = 2). Following these procedures, 33 eligible empirical studies remained for evaluation in the present review.

Study Characteristics

Information about the general characteristics and main methodological properties of all 33 studies can be found in Tables 1 and 2.

Country in Which the Data Were Collected

Regarding the geographic characteristics of the included studies, nine were from China (Ding et al. 2014; Du et al. 2016; Du et al. 2017; Hu et al. 2017; Tian et al. 2018; Wang et al. 2016,2017; Wu et al. 2018; Yao et al. 2017), eight were from South Korea (Choi et al. 2014; Hyun et al. 2015; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017; Lee et al. 2017; Rho et al. 2017; Ryu et al. 2018), three were from Germany (Rehbein et al. 2010; Sariyska et al. 2017; Walther et al. 2012), two were from Australia (Bailey et al. 2013; Metcalf and Pammer 2014), two were from Singapore (Gentile et al. 2011; Liau et al. 2015), two were from the USA (Bargeron and Hormes 2017; Stockdale and Coyne 2018), one was from Spain (Irles and Gomis 2016), one was from the UK (Irvine et al. 2013), one was from Belgium (Deleuze et al. 2017), one was from the Czech Republic (Blinka et al. 2016), and one was from Taiwan (Yen et al. 2017). Additionally, there were two cross-cultural studies. The first one collected data from France, Switzerland, and Belgium (Billieux et al. 2015), the second collected data from Belgium and the UK (Nuyens et al. 2016).

Participants

The 33 reviewed studies comprised 18,128 participants in total. The vast majority of studies recruited more male participants (n = 12,492; 70.1%) than female participants (n = 5333; 29.9%). No information was provided about the participants' gender in two studies (Bargeron and Hormes 2017; Yao et al. 2017) in order to avoid the activation of gender-related stereotypes (Bargeron and Hormes 2017). Twenty-four studies included adult samples and nine studies included adolescent samples (Ding et al. 2014; Du et al. 2016; Du et al. 2017; Irles and Gomis 2016; Hu et al. 2017; Liau et al. 2015; Rehbein et al. 2010; Tian et al. 2018; Walther et al. 2012). Eleven studies comprised student samples (Bailey et al. 2013; Gentile et al. 201; Hu et al. 2017; Irles and Gomis 2016; Liau et al. 2015; Rehbein et al. 2010; Sariyska et al. 2017; Stockdale and Coyne 2018; Walther et al. 2012; Wang et al. 2014 ;Wang et al. 2017); nine studies comprised outpatients (Choi et al. 2014; Ding et al. 2014; Du et al. 2017; Hyun et al. 2015; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017; Ryu et al. 2018; Tian et al. 2018); and seven studies comprised only gamers (Bargeron and Hormes 2017; Billieux et al. 2015; Blinka et al. 2016; Deleuze et al. 2017; Hu et al. 2017; Irles and Gomis 2016; Nuyens et al. 2016). Of the seven studies comprising gamers only (seven studies included gamers and non-gamers), two studies (Billieux et al. 2015; Nuyens et al. 2016) comprised

Table 1 Main characteristics of the studies reviewed (authors, sample size, gender distribution, age range, mean age, and sample characteristics ($N = 33$)

Study	Sample size	Gender distribution (%)	Age range and mean age (SD)	Sample characteristics	Operationalization of IGD	Operationalization of impulsivity
Bailey et al. (2013)	149	53.02% male	Range = 16–30; M_{age} = N/R	University students	Pathological Gaming Scale	Barratt Impulsiveness Scale
Bargeron and Hormes (2017)	257	N/R	Range = Over 18 age; M_{age} = N/R	Regular videogame users (66.5% university student)	DSM-5 Diagnostic Criteria Items (9 Questions)	Barratt Impulsiveness Scale
Billieux et al. (2015)	1.057	87.67% male	Range = 18–66; M_{age} = 26.01 (7.96)	WoW gamers	Internet Addiction Test	French UPPS-P Impulsive Behavior Scale
Blinka et al. (2016)	1.463	90.8% male	Range = 12–69; M_{age} = 24.40 (6.48)	Online gamers	Addiction-Engagement Questionnaire	Dickman's Impulsivity Inventory
Choi et al. (2014)	60	100% male	Range = 15–39; M_{age} = 25.82	15 outpatients with IGD, 15 outpatients with gambling disorder, 15 outpatients with alcohol used disorder and 15 healthy controls	DSM-5 IGD Criteria and Young's Internet Addiction Test	Barratt Impulsiveness Scale; Stop-Signal Test from the Cambridge Neuropsycho-logical Test Automated Battery
Deleuze et al. (2017)	97	87% male	Range = 18–39; M_{age} = 22.21 (3.73)	Gamers	DSM-5 IGD Criteria; Problematic Online Gaming Questionnaire	Short UPPS-P Impulsive Be-havior Scale; Hybrid-Stop Task (Three different trials are measured: Go Trials, No-Go Trials, and Stop-Signal Trials)
Ding et al. (2014)	34	82.35% male	Range = N/R; M_{age} = 16.35	17 adolescent outpatients with IGD and 17 healthy controls	Chen Internet Addiction Scale	Barratt Impulsiveness Scale
Du et al. (2016)	52	100% male	Range = N/R; M_{age} = 17.28 (3,42) for IGD group; M_{age} = 17.48 (2.87) for healthy controls	25 adolescents with IGD and 27 healthy controls (not outpatients)	Internet Addiction Test	Barratt Impulsiveness Scale
Du et al. (2017)	65	100% male	Range = N/R; M_{age} = 17.05	33 adolescent outpatients with IGD and 32 healthy controls	Internet Addiction Test	Barratt Impulsiveness Scale

Table 1 (continued)

Study	Sample size	Gender distribution (%)	Age range and mean age (SD)	Sample characteristics	Operationalization of IGD	Operationalization of impulsivity
Gentile et al. (2011)	3034	72.68% male	N/R	Students (children and adolescents)	Addiction-Engagement Questionnaire	Barratt Impulsiveness Scale
Hu et al. (2017)	375	100% male	Range = 15–17; M_{age} = 16.02 (0.85)	Gamer students	The Online Gaming Addiction Scale	Barratt Impulsiveness Scale
Hyun et al. (2015)	416	89.66% male	Range = 12–45, M_{age} = 20.4 (5.8) for IGD group; Range = 12–40, M_{age} = 21.2 (5.5) for healthy participants	263 outpatients with IGD and 153 healthy controls	IGD Criteria, Internet Addiction Scale	Behavioral Inhibitory System/Behavioral Activation System Scale
Irles and Gomis (2016)	411	61.8% male	Range = 12–16; M_{age} = 13.7 (1.30)	Gamer students	Gaming Addiction Scale for Adolescent	Plutchik Impulsiveness Scale
Irvine et al. (2013)	52	88.46% male	Range = N/R; M_{age} = 24.69 (5.9) for pathological videogame use group; M_{age} = 25.61 (5.87) for healthy participants	26 pathological gamers and 26 healthy participants (not outpatients)	DSM-IV Pathological Gambling Criteria; Game Addiction Scale; Yale — Brown Obsessive Compulsive Scale	UPPS Impulsive Behavior Scale; Information Sampling Task; Delay Discounting Task; Premature Responding Task
Kim et al. 2017a)	77	79.22% male	Range = N/R; M_{age} = 26.5 (6.1) for IGD group; M_{age} = 25(5.7) for OCD group; M_{age} = 24.7(4.7) for healthy participants	27 outpatients with IGD, 24 patients with OCD, and 26 healthy controls	Young Internet Addiction Scale (Korean version)	Barratt Impulsiveness Scale; Go/No Go Task
Kim et al. 2017b	225	89.78% male	Range = N/R; M_{age} = 21.54 (6.91) for IGD group; M_{age} = 28.54(5.41) for AUD group; M_{age} = 23.91(4.55) for OCD group; M_{age} = 22.84 (5.67) for healthy participants	86 outpatients with IGD, 39 outpatients with alcohol use disorder, 23 outpatients with OCD and 77 healthy controls	DSM-5 Criteria and Young Internet Addiction Scale	Stop Signal Test
Lee et al. (2018)	61	100% male	Range = 18–28; M_{age} = 23.5 (2.7)	31 gamers and 30 age-matched healthy controls (not outpatients)	Internet Addiction Test; Clinician-administered interview to confirm the diagnosis of IGD	Barratt Impulsiveness Scale II
Lee et al. (2017)	270	100% male	Range = N/R; M_{age} = 25.5 (4.5) for IGD; M_{age} = 26.9 (5.2) for high	83 outpatients with IGD, 95 adults with high risk of	Young Internet Addiction Scale	Behavioral Activation System

Table 1 (continued)

Study	Sample size	Gender distribution (%)	Age range and mean age (SD)	Sample characteristics	Operationalization of IGD	Operationalization of impulsivity
			risk of alcohol dependence group; M_{age} = 25.9 (6.3) for healthy control participants	alcohol dependence and 92 healthy controls		
Liau et al. (2015)	2154 + 191 (1st + 2nd studies)	70.10% male +73.30%-male	Range = N/R; M_{age} = 10.93 (2.04); M_{age} = 13.02 (0.82)	Students (Children and early adolescents)	Ten-item instrument derived from the pathological gambling items of the DSM-IV	Ten items adapted from the Barratt Impulsiveness Scale
Metcalf and Pammer (2014)	69	100% male	Range = 18–35, M_{age} = 22.82 for gamers; Range = 18–36, M_{age} = 24.86 for control group	47 FPS gamers and 22 healthy controls	Addiction-Engagement Questionnaire	Barratt Impulsiveness Scale; Go/No-Go Task; Continuous Performance Task
Nuyens et al. (2016)	36	83.97% male	Range = 18–24; M_{age} = 21.35 (1.89)	MOBA gamers	Problematic Online Gaming Questionnaire	Single Key Impulsivity Paradigm, s-UPPS-P Impulsive Behavior Scale, Barratt Impulsiveness Scale
Rehbein et al. (2010)	15.168	51.3% male	Range = N/R; M_{age} = 15.3 (0.69)	Students	Video Game Dependency Scale	Two items of the Impulsiveness Inventory
Rho et al. (2017)	3568	57.06% male	Range = 20–49; M_{age} = N/R	481 adults with IGD and 3087 normal gamers (not outpatients)	Internet Addiction Survey 2013; DSM-5 Criteria	Dickman Impulsivity Inventory-Short Version; Behavioral Inhibition System/Behavioral Activation System
Ryu et al. (2018)	118	78.81% male	Range = N/R; M_{age} = 25.54 (5.29) for IGD group; M_{age} = 24.23 (3.92) for healthy controls	67 outpatients with IGD and 56 healthy controls	Young's Internet Addiction Scale	Barratt Impulsiveness Scale
Sariyska et al. (2017)	94	35.11% male	Range = N/R; M_{age} = 23.48(3.55)	University students	Online Gaming Addiction Scale	Barratt Impulsiveness Scale; "Devil's Chest" Experiment
Stockdale and Coyne (2018)	174	68% male	Range = N/R; M_{age} = 20.80 (2.18)	University students	Internet Gaming Disorder Scale (IGD 5 Diagnostic Criteria — nine Questions)	PROMIS Global Health Scale
Tian et al. (2018)	83	51.81% male		42 outpatients with IGD and 41 healthy controls	Young Internet Addiction Scale	Barratt Impulsiveness Scale II

Table 1 (continued)

Study	Sample size	Gender distribution (%)	Age range and mean age (SD)	Sample characteristics	Operationalization of IGD	Operationalization of impulsivity
			Range = N/R; M_{age} = 15.57 (1.17) for IGD group; M_{age} = 15.78 (0.94) for healthy controls			
Walther et al. (2012)	2553	50.07% male	Range = 12–25; M_{age} = 16.7 (3.04)	Students	Video Game Dependency Scale	Inventory of Impulsivity, Risk Behavior and Empathy
Wang et al. (2016)	63	100% male	Range = N/R; M_{age} = 20.95 (2.44) for IGD group; M_{age} = 21.95 (2.37) for healthy controls; M_{age} = 21.72 (2.25) for gamers without being addicted	Students (20 controls without a history of IGD, 20 participants with IGD and 23 players without being addicted to gaming)	Young Internet Addiction Test; DSM-5 Diagnostic Criteria Items (9 Questions)	Behavioral Experiment (Delay Discounting Task and Probabilistic Discounting Task)
Wang et al. (2017)	39	100% male	Range = N/R; M_{age} = 22.1 (3.2) for IGD group; M_{age} = 23.1 (2) for healthy controls	Students (18 participants with IGD and 21 controls without a history of IGD)	Young's Internet Addiction Test; DSM-5 IGD Diagnostic Scale (9 Questions)	Behavioral Experiment (Delay Discounting Task and Probabilistic Discounting Task)
Wu et al. 2018	44	100% male	Range = N/R; M_{age} = 21.4 (1.30) for IGD group; M_{age} = 22 (1.70) for control groups	22 adults with IGD and 22 controls without a history of IGD (not outpatients)	Young Internet Addiction Test; Clinician-administered interview to confirm the diagnosis in accordance with the diagnostic criteria of IGD in the DSM-5	Barratt Impulsiveness Scale II
Yao et al. (2017)	46	N/R	Range = 18–26; M_{age} = 22.28 (1.62) for IGD group; M_{age} = 22 (2.26) for control groups	25 adults with IGD and 21 controls without a history of IGD (not outpatients)	DSM-5 Criteria (Internet game users with scores above five were evaluated as the IGD group); Chen Internet Addiction Scale (CIAS)	Decisional Impulsivity Tasks (DDT); Baloon Analogue Risk Tasks (BART)
Yen et al. (2017)	174	80.46% male	Range = 20–30; M_{age} = 23.38 (2.40) for IGD group; M_{age} = 23.29 (2.34) for control groups	87 adults with IGD and 87 controls without a history of IGD (not outpatients)	DSM-5 Diagnostic Criteria Items (nine questions)	Dickman's Impulsivity Inventory

Massively-Multiplayer Online Role-Playing Games (MMORPGs) players. In addition, seven studies included both gamers and healthy volunteers (Du et al. 2016; Irvine et al. 2013; Lee et al. 2017; Metcalf and Pammer 2014; Wu et al. 2018; Yao et al. 2017; Yen et al. 2017).

Operationalization of Internet Gaming Disorder

Operationalization of a variable comprises describing how a variable is assessed objectively (Dantzker and Hunter 2011). To assess IGD, 15 of the studies the adopted Internet Addiction Test, Young's Internet Addiction Scale, Chen Internet Addiction Scale, or the Internet Addiction Survey (Billieux et al. 2015; Choi et al. 2014; Ding et al. 2014; Du et al. 2016; Du et al. 2017; Hyun et al. 2015; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017, 2018; Rho et al. 2017; Ryu et al. 2018; Tian et al. 2018; Wang et al. 2016,2017; Wu et al. 2018; Yao et al. 2017). Of these 15 studies, half of the studies also assessed IGD using DSM-5 diagnostic criterion items to strengthen the assessment (Choi et al. 2014; Hyun et al. 2015; Kim et al. 2017a; Lee et al. 2018; Rho et al. 2017; Wang et al. 2016,2017; Wu et al. 2018; Yao et al. 2017). In addition, three studies used the Addiction-Engagement Scale which is modified tool based on addiction and engagement portions of General Computing Questionnaire (this scale originally adapted from Computer Apathy and Anxiety Scale) (Blinka et al. 2016; Gentile et al. 2011; Metcalf and Pammer 2014). Two studies used a modified tool based on generalized internet addiction criteria such as the Online Gaming Addiction Scale (Hu et al. 2017; Sariyska et al. 2017). Two studies used the Video Game Dependency Scale which is a modified tool based on non-substance–related addiction according to ICD-10 criteria (Rehbein et al. 2010; Walther et al. 2012). Two studies used the Pathological Gaming Scale, a ten-item instrument derived from the pathological gambling items of the DSM-IV (Bailey et al. 2013; Liau et al. 2015). The remaining seven studies assessed IGD based on gaming addiction/dependency criteria and/or used scales specifically designed to assess problematic gaming (Bargeron and Hormes 2017; Deleuze et al. 2017; Irles and Gomis 2016; Irvine et al. 2013; Nuyens et al. 2016; Stockdale and Coyne 2018; Yen et al. 2017).

The Relationships Between Impulsivity and Internet Gaming Disorder

All number of studies examined the relationship between impulsivity and IGD. Apart from one study which found no relationship (Deleuze et al. 2017), all remaining studies reported that impulsivity was positively correlated with IGD. When the results of regression analysis related with the impulsivity were evaluated, impulsivity was recognized as a predictive factor for IGD in seven studies (Blinka et al. 2016; Gentile et al. 2011; Hu et al. 2017; Hyun et al. 2015; Liau et al. 2015; Rehbein et al. 2010; Ryu et al. 2018). In addition, while self-regulation (Liau et al. 2015), interpersonal relationships, and depression (Ryu et al. 2018) mediated the association between impulsivity and gaming addiction, impulsivity moderated the relationship between positive affective associations and gaming addiction (Hu et al. 2017). Also, dysfunctions of the brain areas involved in behavior inhibition, attention, and emotion regulation were identified as contributing factors for impulse control problems among adolescents with IGD (Ding et al. 2014; Du et al. 2016,2017).

Table 2 Main findings, study limitations, and risk of biases in the studies reviewed ($N = 33$)

Study	Main findings	Study limitations	Risk of biases
Bailey et al. (2013)	Pathological gaming and playing first-person shooter (FPS) games were positively associated with greater impulsivity. The interaction between hours and pathological gaming was also positively related to Barratt Impulsiveness Scale Version II (BIS-II) scores indicating that more pathological symptoms were positively associated with greater impulsivity but just for playing FPS videogames not with playing strategy videogames	Limited representativeness of gamer population due to including only two genres of videogames and student sample; shortcomings of participants demographic information; measurement tool of gaming addiction based on the DSM-IV criteria for gambling addiction	Sampling bias due to non-probability sampling techniques and lack of inclusion of clinical samples; measurement bias due to using modified tool from gambling addiction
Bargeron and Hormes (2017)	Participants meeting criteria for internet gaming disorder (IGD) had significantly elevated motor and attentional impulsivity than the other gamers	Criteria used to assess the presence of IGD had relatively weak psychometric properties; lack of some basic demographic information (gender distribution, exact age range, and mean)	Sampling bias due to non-probability sampling techniques and lack of inclusion of clinical samples
Billieux et al. (2015)	Non-problematic gamers were characterized by low impulsivity traits, and problematic gamers are characterized by high impulsivity traits	Measurement of problematic gaming was based on generalized internet addiction scale; cross-sectional design; self-selection sampling may have led to biased results due to the potential constraints of the variance; findings only related WoW gamers; lack of control group; majority of the sample were male; lack of controlling other types of psychological factors (e.g., social anxiety, schizotypy) that play a role in problematic online gaming	Sampling bias due to non-probability sampling techniques (self-selecting) and lack of inclusion of clinical samples; measurement bias due to using a tool based on internet addiction
Blinka et al. (2016)	Dysfunctional impulsivity was a good predictor of gaming addiction, although it only explained only about 7% of the addiction variance. Problematic gamers high on impulsivity had similar patterns of addiction to non-impulsive gamers, with one exception — they had a significantly higher tendency to relapse. There was no role of impulsivity in gaming engagement. The results showed that problematic gamers high on impulsivity were more prone to relapse and reinstatement	Assessment of gaming addiction was based on addiction and engagement portions of General Computing Questionnaire; cross-sectional design; convenience sampling and self-selection may lead to biased results due to the potential constraints of the variance; findings only related to MMORPGs gamers	Sampling bias due to non-probability sampling techniques (convenience and self-selecting) and lack of inclusion of clinical samples; measurement bias due to using modified tool based on general computing

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
Choi et al. (2014)	The IGD group showed a decreased proportion of successful stops on the stop-signal test compared with the control group. The IGD group scored significantly higher on the BIS-11 as a whole than the control group	Assessment of gaming addiction based on generalized internet addiction scale; small sample size; lack of female participants; cross-sectional design; lack of controlling some variables (anxiety disorders, depression, etc.) that are common in clinical samples	Sampling bias due to collecting data from male-only samples; measurement bias due to using a tool based on internet addiction
Deleuze et al. (2017)	No significant difference between IGD and non-IGD groups concerning impulsivity traits.	Lack of clinical group and lack of controlling treatment-seeking as an excluded criterion; majority of sample were male; self-selected sampling.	Sampling bias due to non-probability sampling techniques (self-selecting) and lack of inclusion of clinical samples.
Ding et al. (2014)	Individuals with IGD subjects had higher scores than controls for BIS-II total scores. Activation of the left superior medial frontal gyrus was correlated with more severe total BIS-11 scores among those with IGD	Assessment of gaming addiction based on internet addiction scale; small sample size; the vast majority of samples were male; omission of some demographic information such as age range; cross-sectional design; lack of controlling some variables (anxiety disorders, depression, etc.) that are common in clinical samples and then can take role in IGD	Measurement bias due to using a tool based on internet addiction
Du et al. (2016)	Those with IGD scored significantly higher on tests of impulsivity compared with healthy controls. Correlations between BIS score and gray matter volume (GMV) of the right dorsomedial prefrontal cortex (dmPFC), the bilateral insula and the orbitofrontal cortex (OFC), the right amygdala and the left fusiform gyrus decreased in the IGD group compared to controls. Results demonstrated that dysfunction of these brain areas involved in the behavior inhibition, attention and emotion regulation might contribute to impulse control problems in adolescents with IGD	Assessment of gaming addiction based on internet addiction scale; small sample size; lack of female participants; omission of some demographic information such as age range; cross-sectional design; lack of controlling some variables such as anxiety, depression that are common in clinical samples	Sampling bias due to collecting data from male-only samples; measurement bias due to using a tool based on internet addiction
Du et al. (2017)	Those with IGD scored significantly higher on test of impulsivity compared with healthy controls. Results concerning negative correlations between impulsivity and the fractional anisotropy values	Assessment of gaming addiction based on internet addiction scale; small sample size; lack of female participants; omission of some demographic information such as age range; cross-sectional	Sampling bias due to collecting data from male-only samples; measurement bias due to using a tool based on internet addiction

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
	within multiple white matter regions in the healthy controls indicated a normal neuro-mechanism of impulse control in the controls, an altered correlation between impulsivity and the fractional anisotropy values on the right corticospinal tract and the occipital white matter was found among adolescents with IGD	design; lack of controlling some variables such as anxiety, depression that are common in clinical samples and then can take role in IGD	
Gentile et al. (2011)	Greater amounts of gaming, lower social competence, and greater impulsivity were risk factors for becoming pathological gamers, whereas depression, anxiety, social phobias, and lower school performance acted as outcomes of pathological gaming	Assessment of gaming addiction based on addiction and engagement portions of General Computing Questionnaire; majority of sample was male; omission of some demographic information such as mean and age range	Sampling bias due to non-probability sampling techniques (convenience sampling); measurement bias due to using modified tool based on general computing
Hu et al. (2017)	Impulsivity was significantly and positively associated with online gaming addiction in adolescents. Also, impulsivity moderated the relationship between positive affective associations and online gaming addiction	Assessment of gaming addiction based on generalized internet addiction scale; cross-sectional design; lack of female participants and sample heterogeneity	Sampling bias due to non-probability sampling techniques (convenience sampling), lack of inclusion female and clinical sample; measurement bias due to using modified tool from internet addiction
Hyun et al. (2015)	Those with IGD scored significantly higher on impulsivity compared with healthy controls. Impulsivity was found one of the strongest psychological risk factors for online gaming addiction in patients with online gaming addiction	Assessment of gaming addiction based on internet addiction scale; cross-sectional design; majority of IGD samples were male, so generalizability of the results to online gaming addiction in females is limited	Measurement bias due to using a tool based on internet addiction
Irles and Gomis (2016)	Impulsiveness was associated with addiction to videogames in both males and females	Lack of control group; cross-sectional design	Sampling bias due to non-probability sampling techniques (convenience sampling)
Irvine et al. (2013)	Pathological gaming was associated with impaired decisional impulsivity with negative consequences in task performance. In the delay discounting task, pathological gamers made more impulsive choices, preferring smaller immediate over larger delayed rewards	Cross-sectional design; generalizability of results was limited because majority of sample was male and self-selected sampling was used; some demographic information such as age range and sample characteristics was limited	Sampling bias due to non-probability sampling techniques (self-selected sampling)
Kim et al. (2017a)	Impulsiveness was higher in the IGD group than in the healthy participants.	Cross-sectional design; generalizability of results was limited because many of the IGD patients'	Measurement bias due to using a tool based on internet addiction

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
	Severity of IGD and impulsivity correlated positively	addiction was less severe and majority of IGD sample was male	
Kim et al. (2017b)	Within the domain of impulsivity, IGD and obsessive-compulsive disorder (OCD) groups had the worst performance compared to healthy participants. Both the IGD and OCD groups shared impairment in inhibitory control functions as well as cognitive inflexibility. Neurocognitive dysfunction in IGD was associated with this feature of impulsivity and compulsivity of behavioral addiction rather than impulse dyscontrol alone	Assessment of problematic gaming based on generalized internet addiction scale; cross-sectional design; generalizability of results was limited because majority of the sample was male	Measurement bias due to using a tool based on internet addiction
Lee et al. 2018	Participants with IGD scored significantly higher on test of impulsivity compared with healthy controls	Assessment tool for assessing gaming addiction severity based on generalized internet addiction scale; cross-sectional design; lack of female participants; small sample size	Sampling bias due to non-probability sampling techniques and lack of inclusion female; measurement bias due to using a tool based on internet addiction
Lee et al. 2017)	The severity of IGD was positively correlated with impulsiveness	Assessment and operationalization of gaming addiction based on general internet addiction; sample heterogeneity due to lack of female participants; cross-sectional design; omission of some demographic information such as age range	Sampling bias due to non-probability sampling techniques and lack of inclusion female; measurement bias due to using a tool based on internet addiction
Liau et al. (2015)	Impulsivity was significantly and positively associated with gaming addiction. Self-regulation mediated the relationship between impulsivity and gaming addiction	Assessment tool for assessing gaming addiction based on DSM-IV gambling addiction criteria; cross-sectional design; convenience sampling	Sampling bias due to non-probability sampling techniques; measurement bias due to using tool based on gambling addiction
Metcalf and Pammer (2014)	Addicted First-Person-Shooter (FPS) gamers had significantly higher levels of trait impulsivity on the BIS compared to controls. Addicted FPS gamers also had significantly higher levels of disinhibition in a go/no-go task and inattention in a continuous performance task compared to controls	Assessment of gaming addiction based on addiction and engagement portions of General Computing Questionnaire; sample heterogeneity due to lack of female participants; sample size was limited; cross-sectional design; findings related to FPS gamers only	Sampling bias due to non-probability sampling techniques; measurement bias due to using tool based on general computing

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
Nuyens et al. (2016)	Positive associations were found between self-reported impulsivity traits and signs of excessive multiplayer online battle arena (MOBA) game involvement. Also, impaired ability to postpone rewards in an experimental laboratory task was strongly related to problematic patterns of MOBA game involvement	Generalizability of results was limited because majority of the sample was male; small sample size; lack of control group; cross-sectional design	Sampling bias due to non-probability sampling techniques
Rehbein et al. (2010)	Higher levels of impulsiveness contributed to videogame dependency	Assessment of gaming addiction based on non-substance-related addiction according to ICD-10 criteria; impulsiveness measured using two items of the Impulsiveness Inventory; cross-sectional design; control group data were not considered in the analysis	Measurement bias due to using tool based on non-substance related addiction and impulsivity measurement that was strongly reduced in size (using only two items)
Rho et al. (2017)	Dysfunctional impulsivity was found to be significantly associated with gaming addiction	The tool for assessing gaming addiction severity based on internet addiction scale that had not been used validated before by previous studies; some demographic data were limited; cross-sectional design	Measurement bias due to using tool based on internet addiction
Ryu et al. (2018)	High impulsivity increased the risk of IGD. Mediation analysis demonstrated full mediation effects of interpersonal relationships and depression on the association between impulsivity and IGD symptoms in the IGD group	Assessment of gaming addiction based on generalized internet addiction scale; generalizability of results was limited because the vast majority of samples were male and small sample size; cross-sectional design	Measurement bias due to using tool based on internet addiction
Sariyska et al. (2017)	Self-report measures of risk-taking were not associated with gaming addiction, although the experimental measure of impulsivity was positively correlated with gaming addiction	Assessment of gaming addiction based on generalized internet addiction scale; limited representativeness of gamer population due to including student-only sample; shortcomings of participants demographic information; cross-sectional design	Sampling bias due to non-probability sampling techniques (convenience sampling), lack of inclusion of clinical sample; measurement bias due to using tool based on internet addiction
Stockdale and Coyne (2018)	Participants with IGD had poorer mental health and cognitive functioning including poorer impulse control compared to controls	Limited representativeness of gamer population due to including student-only sample; shortcomings of participants demographic information; limited	Sampling bias due to non-probability sampling techniques (convenience sampling), lack of inclusion of clinical sample

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
		scope of the scale in terms of impulsivity; cross-sectional design	
Tian et al. (2018)	Adolescents with IGD had a larger degree of delay discounting (i.e., more impulsive decision-making), regardless of the outcome amount and valence, and higher scores on all three subscales of the BIS-11 than the comparison group	Generalizability of results were limited due to small sample size; shortcomings of participant demographic information; assessment of gaming addiction based on generalized internet addiction scale; cross-sectional design	Measurement bias due to using tool based on internet addiction
Walther et al. (2012)	High impulsivity was associated with problematic computer gaming	Assessment of gaming addiction based on non-substance-related addiction according to ICD-10 criteria; limited representativeness of gamer population due to student-only sample; cross-sectional design	Sampling bias due to non-probability sampling techniques and lack of clinical samples; measurement bias due to using a tool that originally based on non-substance-related addiction according to ICD criteria for assessing IGD
Wang et al. (2016)	Regular videogame users (RGU) were capable of inhibiting impulse due to additional cognitive endeavor and the participants with IGD have deficit in decision-making and impulsive control	Assessment of gaming addiction severity based on generalized internet addiction scale; generalizability of results was limited due to lack of female participants and small sample size; shortcomings of participants demographic information; cross-sectional design; lack of controlling several variables (IQ, socioeconomic status, self-efficiency)	Sampling bias due to non-probability sampling techniques and lack of inclusion female participants; measurement bias due to using tool based on internet addiction
Wang et al. (2017)	The IGD group was more impulsive than the control group, showed deficits in making decisions, and tended to pursue immediate satisfaction	Generalizability of results was limited due to lack of female participants and small sample size; shortcomings of participants demographic information; cross-sectional design	Sampling bias due to non-probability sampling techniques and lack of inclusion female participants
Wu et al. 2018	Participants with IGD scored significantly higher on test of impulsivity compared with healthy controls	Assessment of gaming addiction severity based on generalized internet addiction scale; generalizability of results was limited due to lack of female participants and small sample size; shortcomings of participants demographic information; cross-sectional design	Sampling bias due to non-probability sampling techniques (self-selecting) and lack of inclusion of clinical samples; measurement bias due to using a tool based on internet addiction
Yao et al. (2017)	Participants with IGD showed greater intertemporal and risky decisional impulsivity than healthy	Assessment of gaming addiction severity based on generalized internet addiction scale; lack of some	Sampling bias due to non-probability sampling techniques (self-selecting) and lack of inclusion

Table 2 (continued)

Study	Main findings	Study limitations	Risk of biases
	controls on both the delay discounting task (DDT) and balloon analogue risk task (BART) at baseline	basic demographic information (gender distribution); generalizability of results was limited due to small sample size	of clinical samples; measurement bias due to using a tool based on internet addiction
Yen et al. (2017)	Young adults with IGD had higher impulsivity scores than those without IGD	Generalizability of results were limited because majority of the sample was male and small sample size; cross-sectional design	Sampling bias due to non-probability sampling techniques and lack of inclusion of clinical samples

Risk of Bias in Individual Studies

With regard to the process of assessing risk of bias in each study, sampling bias and measurement bias were assessed. On these biases, apart from seven studies (Ding et al. 2014; Hyun et al. 2015; Kim et al. 2017a; Kim et al. 2017b; Rehbein et al. 2010; Rho et al. 2017; Tian et al. 2018), all the remaining 26 studies were rated as having risk of sampling bias due to (i) adopting non-probability sampling techniques and/or self-selected samples, (ii) omission of female samples, and/or (iii) omission of clinical samples. Additionally, measurement bias was rated as high risk in most of the studies due to using internet addiction scales to assess IGD (Billieux et al. 2015; Choi et al. 2014; Ding et al. 2014; Du et al. 2016; Du et al. 2017; Hyun et al. 2015; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2018; Lee et al. 2017; Rho et al. 2017; Ryu et al. 2018; Tian et al. 2018; Wang et al. 2016,2017; Wu et al. 2018; Yao et al. 2017), adopting modified tools based on anxiety related with general computing (Blinka et al. 2016; Gentile et al. 2011; Metcalf and Pammer 2014), internet addiction (Hu et al. 2017; Sariyska et al. 2017), or non-substance addiction criteria (Bailey et al. 2013; Liau et al. 2015; Rehbein et al. 2010; Walther et al. 2012).

Methodological Features of Studies

In regard to key methodological features of the studies, all studies were quantitative in nature. The majority of the studies (n = 25) employed a quantitative cross-sectional design (Bailey et al. 2013; Bargeron and Hormes 2017; Billieux et al. 2015; Blinka et al. 2016; Choi et al. 2014; Deleuze et al. 2017; Ding et al. 2014; Du et al. 2016; Du et al. 2017; Irvine et al. 2013; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017; Lee et al. 2018; Metcalf and Pammer 2014; Nuyens et al. 2016; Rehbein et al. 2010; Rho et al. 2017; Sariyska et al. 2017; Stockdale and Coyne 2018; Tian et al. 2018; Walther et al. 2012; Wang et al. 2016,2017; Wu et al. 2018) and six studies adopted a correlational mixed-methods cross-sectional design (Hu et al. 2017; Hyun et al. 2015; Irles and Gomis 2016; Liau et al. 2015; Ryu et al. 2018; Yen et al. 2017). Additionally, two studies employed a longitudinal design (Gentile et al. 2011; Yao et al. 2017). Excluding 12 studies that combined both self-report questionnaires and clinical interviews (Choi et al. 2014; Ding et al. 2014; Du et al. 2017; Hyun et al. 2015; Irvine et al. 2013; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017; Ryu et al. 2018; Tian et al. 2018; Wu et al. 2018; Yao et al. 2017) and one study which included only a clinical interview based on DSM-5 IGD Criteria — 9 Questions (Yen et al. 2017), the remaining 20 studies used self-report surveys to collect data. Moreover, while five studies employed online surveys with self-report measures for assessing IGD (Bargeron and Hormes 2017; Billieux et al. 2015; Blinka et al. 2016; Rho et al. 2017; Stockdale and Coyne 2018), 28 studies used offline "paper-and-pencil" survey methods (Bailey et al. 2013; Choi et al. 2014; Deleuze et al. 2017; Ding et al. 2014; Du et al. 2016; Du et al. 2017; Gentile et al. 2011; Hu et al. 2017; Hyun et al. 2015; Irles and Gomis 2016; Irvine et al. 2013; Kim et al. 2017a; Kim et al. 2017b; Lee et al. 2017; Lee et al. 2018; Liau et al. 2015; Metcalf and Pammer 2014; Nuyens et al. 2016; Rehbein et al. 2010; Ryu et al. 2018; Sariyska et al. 2017; Tian et al. 2018; Walther et al. 2012; Wang et al. 2016,2017; Wu et al. 2018; Yao et al. 2017; Yen et al. 2017). As to the sampling methods adopted, all the studies used convenience sampling or self-selected sampling to recruit participants. Several types of limitations were determined across all 33 studies (see Table 2) and can be grouped into three types: (a) sampling problems; (b) measurement problems; and (c) lack of longitudinal studies (i.e., excluding two studies, all of the remaining studies were cross-sectional). Sampling problems included (i) employing non-probability sampling methods ($n = 24$); (ii) sampling homogeneity due to including male-only samples within some studies ($n = 10$); (iii) the omission of clinical samples within the majority of studies ($n = 24$); and (iv) low sample sizes ($n = 15$ — five outpatient studies had samples sizes of 83 or fewer, and 10 other studies had sample sizes of 97 or fewer). Measurement problems included employing modified measurements that originally designed for evaluating generalized internet addiction and not validated by previous studies.

Discussion

The present systematic review identified peer-reviewed published studies investigating the association between impulsivity and Internet Gaming Disorder (IGD). The present study also extracted data from the reviewed studies including: (i) country in which data were collected, (ii) main characteristics of participants, (iii) operationalization of IGD, (iv) the association between impulsivity and IGD, (v) risk of bias in individual researches, and (vi) methodological features of the studies.

In terms of geographic location, more than half of the studies ($n = 20$) were conducted in an Asian context, with the others being conducted either in European countries and/or the USA. As for the participants involved in the studies reviewed, similar patterns appeared across the studies. More specifically, studies were prone to comprise: (i) more male participants than female, (ii) adult samples rather than adolescent samples, (iii) student samples rather than clinical samples and/or individuals from the general population, and (iv) non-MMORPG players rather than MMORPG players. Based on these observations, future studies investigating the association between impulsivity and IGD should include other participants (children and adolescents, females, clinical samples, and players from a variety of gaming genres) to enhance external validity.

With regard to the operationalization of IGD, while about a quarter reviewed studies used gaming addiction criteria, the others employed a modified measurement based on either internet addiction criteria, substance-related addiction criteria, or non-substance–related addiction criteria (e.g., pathological gambling criteria). Adopting such scales severely limits the reliability of the cross-cultural studies (Pontes and Griffiths 2014). In future studies, validated instruments specifically designed to assess IGD should be adopted and tested in different settings to improve cross-cultural reliability (Griffiths et al. 2014).

The main objective of the present review was to identify studies evaluating the association between impulsivity and IGD. Results demonstrated that apart from one study (Delueze et al. 2017), all of the remaining studies reported a positive association between impulsivity and IGD. Possible explanations for this consistent finding appear to indicate that altered neurobiological structures detected in participants with impulsivity may explain some of the relationship between impulsivity and internet gaming disorder. It is believed that impulsivity occurs as a result of neuropsychological impairments in attention and executive functions. In addition, although the causal relationships are not clearly defined, it has been argued that the clinical features of IGD may be related to structural abnormalities in the brain (Park et al. 2016). Some studies addressing gaming addiction have identified structural abnormalities within brain regions known to be associated with executive control such as anterior cingulate cortex (ACC), supplementary motor area (SMA), prefrontal and parietal cortices (Bush et al. 2000; Nachev et al. 2008; Crowe et al. 2013), and therefore IGD has been implicated with impairments in executive control (Du et al. 2016; Wang et al. 2016). Voxel-based morphometry (VBM) studies have shown that, in addition to the ACC, lower gray matter volume within dorsolateral prefrontal cortex (DLPFC) and orbitofrontal cortex (OFC) — which are well known to be associated with executive control — are related with IGD (Yuan et al. 2011). Furthermore, detecting a negative correlation between impulsivity and gray matter volume in the ACC and SMA has suggested that high impulsivity among gaming-addicted adolescents may be derived from structural abnormalities in brain regions involved in executive control (Lee et al. 2017).

More specifically, it has been reported that the most affected brain region is the ACC in IGD participants (Lee et al. 2017). As aforementioned, this region, which is involved in executive control, is particularly effective in the conflict monitoring (Botvinick et al. 2001) and error processing (Kiehl et al. 2000). The capacity for conflict and error monitoring is closely implicated with impulse control and delay of gratification (Checa et al. 2014). In parallel, Lee et al. (2014) showed that low-level gray matter volume in the ACC was associated with impulsivity among gaming addicts. Furthermore, the role of the ACC is emphasized in associating executive function with reward-based decision-making (Holroyd and Yeung 2012; Shenhav et al. 2013). In other words, the changes/differences in/of the ACC detected among gaming addicts may play an important role in the dysfunctional relationship between executive control and reward-seeking. This appears to support the I-PACE model of IGD (Brand et al. 2016). In addition, gaming addicts have lower gray matter volume within the SMA compared to control groups (Lee et al. 2014). It is known that abnormalities in the SMA, which has an important role in linking cognition to behavior (Nachev et al. 2008), cause response prevention deficits (Picton et al. 2007).

In parallel, a functional imaging study showed lower SMA activation in participants with IGD compared to controls in the response prevention task (Chen et al. 2015). DLPFC is a brain area involved in behavioral inhibition, reward processing, and decision-making (Hampshire et al. 2010; Menon and Uddin 2010; Staudinger et al. 2011). In particular, impaired functional connectivity in the bilateral prefrontal lobe has been found among IGD participants (Wang et al. 2015). IGD participants have been shown to exhibit lower activation in the left DLPFC compared to healthy groups while selecting the delayed option (Wang et al. 2017). Hoffman et al. (2008) showed that methamphetamine addicts had lower activation in DLPFC in delayed decisions compared with a healthy group. The dual-system mode posits that the DLPFC is involved in weighting/evaluating delayed rewards (McClure et al. 2004; McClure et al. 2007). It has also been shown that the DLPFC is responsible for postponing delayed rewards, and that activation in the DLPFC is negatively associated with increased delay time (Ballard and Knutson 2009). In other words, decreased brain activities in the DLPFC detected among gaming addicts may signify that they have potential impairments in assessing the magnitude and postponement of rewards (Wang et al. 2017).

Even if decision-making times increase, all of the information concerning options may not be unified/integrated, and therefore, their decision-making capacity may be negatively affected (Wang et al. 2017). Furthermore, it is thought that reduced functional connectivity strength between the DLPFC and the caudate among gaming addicts indicates that the DLPFC's effective modulation of rewards has been disrupted (Yuan et al. 2017). A positive relationship between response time and severity of gaming addiction has been reported (Wang et al. 2017). This means that as the severity of gaming addiction increases, the time required to make choices increases. This relationship supports the assumption of impaired assessment skills of gaming addicts on the delayed features to a certain extent (Wang et al. 2017).

Taken together, it is argued that unconscious short-term gains in IGD are experienced and that this may be related to weak reward evaluation skills (Wang et al. 2017). Because of diminished activity in the brain regions associated with working memory and executive control, gaming addicts show decreased ability to inhibit their impulses for short-term gains (Wang et al. 2016). In addition to the known role in reward processing, the DLPFC is responsible for executive functions such as multi-attribute/qualified decision-making and response inhibition (Steinbeis et al. 2012; Zysset et al. 2006). More specifically, studies have shown that DLPFC activations increase when individuals experience self-control (Hare et al. 2009). In addition, decreased activation of the inferior frontal gyrus (IFG) among gaming addicts has been determined during the inhibition processing (Wang et al. 2017).

The IFG is an effective region for cognitive control and impulse inhibition (Brown et al. 2012; Tops and Boksem 2011). The IFG is also responsible for the prevention of strong responses needed to abandon immediate gratification, self-control, seeking long-term gains (Aron et al. 2004; Garavan et al. 2002; Menon et al. 2001), and organizing (and establishing) a flexible relationship between outcomes and advantageous behaviors (actions) (Ernst and Paulus 2005). From this point of view, it is thought that the low brain activity within the DLPFC and IFG among gaming addicts indicates an impaired ability to control their behaviors and impulses (Wang et al. 2017). Many studies concerning IGD have reported diminished capacity for responding to immediate rewards and altered brain activities in the DLPFC (Liu et al. 2017) and IFG (Lin et al. 2015; Wang et al. 22016).

As altered activity in the DLPFC and IFG increases, impulsivity levels among gaming addicts increase (Wang et al. 2017). Moreover, recreational online gamers (ROGs) are better than gaming addicts in both risk assessment and impulse control (Wang et al. 2016). Apart from the IFG, the medial frontal gyrus (MFG) is closely related with reward mechanisms and risky decision-making (Goldstein and Volkow 2011). The enhanced brain activities in the MFG and IFG under risky situations among ROGs indicated increased effort in assessing the aversive results of risky choices (Wang et al. 2016). It has been shown that ROGs need longer response time than gaming addicts for making decisions by considering the amount of reward, risk level, and predisposition to control (inhibit) impulse (Wang et al. 2016). Furthermore, the negative relationship between probabilistic discounting rate and MFG activation among gaming addicts can be explained by the fact that these individuals are more sensitive to large rewards (Wang et al. 2016).

Consistently, studies have demonstrated that gaming addicts have diminished loss sensitivity and enhanced reward sensitivity (Dong et al. 2011). Therefore, increased impulsivity and disrupted (impaired) risk assessment among gaming addicts may be associated with abnormal functioning in the IFG and MFG (Wang et al. 2016). Taken together, ROGs are better at controlling impulse and making decisions than gaming addicts, which may differentiate the two groups from each other (Wang et al. 2016). Apart from behavioral inhibition and attention, a negative association between impulsivity and gray matter volumes has been detected in brain areas associated with emotion regulation (Du et al. 2016). In other words, high-level impulsivity among adolescents with gaming addiction may also be related to functional or structural differences (changes) in the dmPFC and OFC, which are essential for emotion regulation (Du et al. 2016). A recent study suggested that the reduction of the gray matter volume in the bilateral amygdala and the increase of the connectivity between the prefrontal cortex/insula and the amygdala may indicate emotion dysregulation among gaming addicts (Ko et al. 2015).

In sum, impairments detected in emotion regulation may contribute to the high level of impulsivity among gaming addicts (Du et al. 2016).

On the other hand, only one study found no association between impulsivity and IGD in either self-report questionnaires or laboratory tasks (Deluze et al. 2017). The absence of differences between groups may have been due to the differences in sample-specific characteristics, task design, task difficulty, and/or participant intelligence. Ding et al. (2014) suggested that these factors may affect the association between IGD and impulsivity. In addition, game genre is also a variable that can affect this relationship, and even determine the direction of this relationship. For instance, exposure to first-person-shooter (FPS) games (Bailey et al. 2013; Metcalf & Pammer 2013) and multiplayer online battle arena (MOBA) games (Nuyens et al. 2016) has been found to be positively related to impulsivity, whereas exposure to strategy games has been negatively related to impulsivity (Bailey et al. 2013). Potential explanations for the differential influence of game genre are that games have different structural characteristics and expect gamers to perform different goals (Bailey et al. 2013). Games with short, intense gaming sessions and daily updated international rankings may predispose to "binge" involvement (Nuyens et al. 2016), whereas in a strategy game, it is likely that there are social repercussions of impulsive decisions, because success in this game often requires collaboration with a team (Bailey et al. 2013).

Apart from seven studies (Ding et al. 2014; Hyun et al. 2015; Kim, M. et al. 2017; Kim, Y. et al. 2017; Rho et al. 2017; Ryu et al. 2018; Tian et al. 2018) — a high risk of sampling bias was found in all 26 remaining studies, closely followed by measurement bias. Additionally, most of the studies employed cross-sectional designs and only six studies adopted a mixed-method design (Hu et al. 2017; Hyun et al. 2015; Irles & Gomis 2015; Liau et al. 2015; Ryu et al. 2018; Yen et al. 2017). Apart from the 12 studies that combined both self-report questionnaires and clinical interviews (Choi et al. 2014; Ding et al. 2014; Du et al. 2017; Hyun et al. 2015; Irvine et al. 2013; Kim, M. et al. 2017; Kim, Y. et al. 2017; Lee Y. S. et al. 2017; Ryu et al. 2018; Tian et al. 2018; Wu et al. 2018; Yao et al. 2017) and one study which included clinical interviews based on DSM-5 IGD Criteria (Yen et al. 2017), all the remaining studies adopted self-report surveys to collect data. Apart from five studies employing online self-report measures assessing IGD (Bargeron & Hormes 2016; Billieux et al. 2014; Blinka et al. 2016; Rho et al. 2017; Stockdale and Coyne 2018), the remaining studies used offline "paper-and-pencil" survey methods, and only two studies employed a longitudinal design (Gentile et al. 2011; Yao et al. 2017). Taken together, all of these findings arguably restrict the generalizability of the results of the reviewed studies because in almost all cases, causality cannot be established. Consequently, future studies should adopt longitudinal and experimental designs, probability-sampling methods, online surveys with self-report measures, and clinical interviews. Finally, as aforementioned, several types of limitations identified were broadly grouped into three types: (i) sampling problems, (ii) measurement problems, and (iii) lack of longitudinal studies (i.e., all studies were cross-sectional). Attention should be paid to these limitations in order to improve the quality of studies published in the IGD field.

Despite the comprehensive search across databases, some related studies may have been missed due to including only studies published in English and Turkish, selected search terms, and database limitations. Additionally, important data might be contained in non-peer reviewed studies, and unpublished theses and dissertations.

Conclusions

The findings obtained in the present review make evident the usefulness of examining the role of impulsivity in the etiology of IGD. According to the findings, impulsivity should be continued to be researched. Future research might enhance the understanding of IGD by providing (i) findings on gender differences regarding risk factors underpinning IGD; (ii) cross-cultural data concerning IGD; (iii) data concerning specific game genres; and (iv) findings on self-regulation, interpersonal problems, and depression as moderator or mediator factor in the association between impulsivity and IGD. Such information should be considered in developing treatment programs for participants with IGD who report high impulsivity.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Not applicable.

Informed Consent Not applicable.

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