Chapter 11
Psychometric Assessment of Internet Gaming Disorder in Neuroimaging Studies: A Systematic Review

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Abstract *Background*: Little attention has been paid to research on Internet Gaming Disorder (IGD) using neuroimaging techniques even though this type of research is of key importance for the formal recognition of IGD as an independent disorder. *Aims*: The aim of the present study was to conduct a systematic review of some of the methodological and assessment characteristics in neuroimaging studies that have been published from May 2013 to January 2016 and that have assessed IGD whilst also having used a neuroimaging technique to gather neurobiological evidence of this potential disorder. *Methods*: Systematic electronic searches using strict inclusion and exclusion criteria were conducted on ProQuest (in the following scholarly databases: ProQuest Psychology Journals, PsycARTICLES, PsycINFO, Applied Social Sciences Index and Abstracts, and ERIC) and on MEDLINE to identify potential eligible studies. *Results*: A total of 853 studies were screened and after a careful systematic selection process, 14 studies were found to meet the inclusion criteria. Based on the findings, it was concluded that research on IGD using neuroimaging techniques is on the rise. Additionally, this systematic review offers ten practical recommendations to authors based on the methodological and assessment shortcomings of extant empirical studies on IGD using neuroimaging techniques. *Conclusions*: It is envisaged that the results of this study will help improve the overall quality of research on IGD using neuroimaging techniques.

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11.1 Introduction

Since the introduction of the concept of **Internet Gaming Disorder** (IGD) as a tentative disorder in the latest (fifth) edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association 2013), research into IGD using neuroimaging techniques has steadily increased. Neuroimaging studies appear to offer several advantages over traditional self-report and clinical research by highlighting specific areas of the brain involved in the development and maintenance processes of addiction (Kuss and Griffiths 2012a). More recently, the APA (2013) defined IGD as a behavior that refers to "persistent and recurrent engagement in video games, often with other players, leading to clinically significant impairments or distress as indicated by five (or more) of the following nine criteria in a 12-month period: (1) preoccupation with games; (2) withdrawal symptoms when gaming is taken away; (3) tolerance, resulting in the need to spend increasing amounts of time engaged in games; (4) unsuccessful attempts to control participation in games; (5) loss of interest in previous hobbies and entertainment as a result of, and with the exception of, games; (6) continued excessive use of games despite knowledge of psychosocial problems; (7) deceiving family members, therapists, or others regarding the amount of gaming; (8) use of games to escape or relieve negative moods; and (9) jeopardizing or losing a significant relationship, job, or education or career opportunity because of participation in games (p. 795)."

Numerous studies have systematically reported numerous harmful effects games can have on human health because of their potentially addictive features (Eichenbaum et al. 2015; Lehenbauer-Baum et al. 2015; Schmitt and Livingston 2015) and overall detrimental effects (Brunborg et al. 2014; Haghbin et al. 2013; Hull et al. 2013; Kuss and Griffiths 2012b) both from a psychosocial and neuroscientific standpoint. From a psychosocial viewpoint, such harmful effects related to addiction to gaming can include decreased levels of exercise and sports (Henchoz et al. 2014), sacrificing work, education, hobbies, socializing, time with partner/family, and sleep (Griffiths et al. 2004), impaired decision-making (Yao et al. 2015), poorer psychosomatic health (Wittek et al. 2015), decreased emotional and behavioral functioning (Baer et al. 2012), increased stress (Snodgrass et al. 2014), greater incidence of psychiatric symptoms (Király et al. 2015a, b; Vukosavljevic-Gvozden et al. 2015), lower expected college engagement and grades in adolescent students (Schmitt and Livingston 2015), decreased academic performance (Brunborg et al. 2014), lower levels of sociability, self-efficacy and satisfaction with life (Festl et al. 2013), in addition to other psychiatric disorders and abnormal behaviors (see Griffiths et al. 2012, 2015, 2016; Kuss and Griffiths 2012b).

On the other hand, from a neuroscientific perspective, a systematic review of neuroimaging studies of Internet and gaming addiction (Kuss and Griffiths 2012a) found that excessive Internet use and gaming is associated with changes on the behavioral, as well as molecular and neural circuitry levels, providing objective evidence of the biological similarity between Internet and gaming addiction and more traditional substance-related addictions. Previous studies (e.g., Dong et al.

2012, 2013; Dong and Potenza 2014; Liu et al. 2015) have found that IGD is associated with abnormal activations in frontal, insular, temporal, and parietal cortices when affected individuals perform tasks related to impulse control. Additionally, previous structural studies have found that IGD was associated with structural abnormalities in gray matter, such as decreased lower gray matter density in the bilateral inferior frontal gyrus, left cingulate gyrus, insula, right precuneus, and right hippocampus (Lin et al. 2015a, b). In addition, IGD has also found to be associated with lower white matter density in the inferior frontal gyrus, insula, amygdala, and anterior cingulate, brain regions that are involved in decision-making, behavioral inhibition, and emotional regulation (Lin et al. 2015a, b).

11.1.1   Objectives

Since IGD may be related to a wide range of health and psychiatric disorders as reported by previous studies, it has become vital to understand and evaluate the potential methodological shortcomings of research on IGD using neuroimaging techniques in order to refine future research. For this reason, and given the ongoing debates surrounding the issue of assessment of IGD and the need for unification in the way assessment of this disorder is carried out (Griffiths et al. 2014, 2015, 2016; Petry and O'Brien 2013; Petry et al. 2015, 2014; Pontes and Griffiths 2015b), the present chapter systematically reviews the extant neurobiological evidence of studies that have adopted commonly used types of neuroimaging techniques to investigate the psychobiology of IGD. More specifically, the main aim of this chapter is to investigate what are (if any) the caveats and potential biases and limitations stemming from an assessment of IGD during participant recruitment in such studies. The secondary objective of this chapter is to ascertain the publication rates of IGD studies using neuroimaging techniques as of May 2013 and briefly summarize the main findings of these studies. To the best of the authors' knowledge, no previous review has attempted to summarize and critique the existing evidence regarding the assessment of IGD in neuroimaging studies (as opposed to describing neuroimaging evidence for Internet and gaming addiction; Kuss and Griffiths 2012b). This chapter contributes a critical discussion of current practices in the assessment of IGD and may pave the way for new methodologically robust research.

11.2   Method

11.2.1   Eligibility Criteria

To be eligible for inclusion in this systematic review, only original studies investigating IGD and its associated neurological correlates were included. Additionally,

eligible studies had to: (i) assess IGD or direct effects of gaming on neurological functioning, (ii) be an empirical study, (iii) use neuroimaging techniques, (iv) be published in a scholarly peer-reviewed journal, and (v) be written in English, Spanish, German, Polish, or Portuguese language. Searches were limited to articles published from May 2013 to January 2016, because IGD was officially defined and conceptualized by the APA in May 2013, which followed the publication of psychometric tools using this framework to assess IGD. Studies were excluded from review if they were (i) unpublished dissertation and thesis studies, (ii) single-case reports ($N = 1$), and (iii) review studies.

11.2.2 Information Sources and Search

The identification of studies was carried out by performing electronic searches on *ProQuest,* which included the following databases: *Applied Social Sciences Index and Abstracts (ASSIA), ERIC, ProQuest Psychology Journals, PsycARTICLES,* and *PsycINFO*. An additional independent search was carried out on *MEDLINE* to enhance the accuracy of the results regarding the systematic search of relevant studies. The search strategy adopted to identify relevant papers in the aforementioned databases sought to include and be able to retrieve the most common types of neuroimaging techniques employed in research on IGD (i.e., electroencephalogram [EEG], positron emission tomography [PET], single-photon emission computed tomography [SPECT], functional magnetic resonance imaging [fMRI], structural magnetic resonance imaging [sMRI], diffusion-tensor imaging [DTI]) as reported in a previous systematic review (i.e., Kuss and Griffiths 2012a). As a result, the following search strategy was used:

(patholog* OR problem* OR addict* OR compulsive OR dependen* OR disorder*) AND (video OR computer OR internet) gam* AND (neuroimaging OR eeg OR pet OR spect or fmri OR smri OR dti).

11.2.3 Study Selection and Data Collection Processes

Following the initial literature searches, each study's title and abstract were screened for eligibility. Full texts of all potentially relevant studies were then retrieved and further examined for eligibility. The flow diagram in Fig. 11.1 details the selection process. Information from the included studies was recorded in an electronic spreadsheet after in-depth analysis. The overall data extracted from the studies reviewed subdivided into two larger overarching groups: (i) methodological
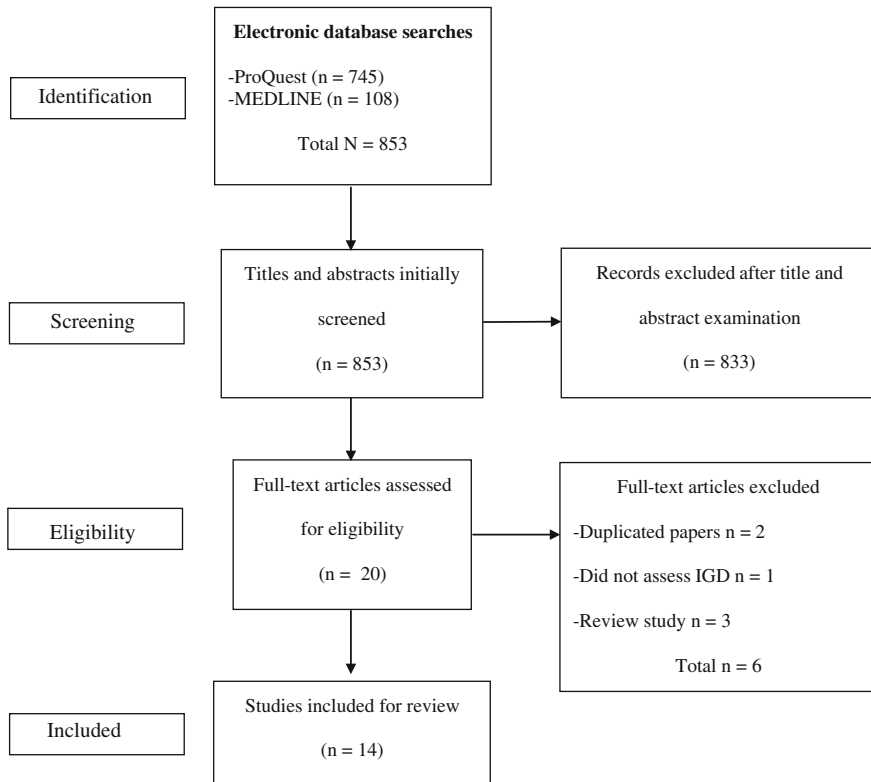
Electronic database searches

-ProQuest (n = 745)
-MEDLINE (n = 108)

Total N = 853

Identification

Titles and abstracts initially
screened
(n = 853)

Records excluded after title and
abstract examination
(n = 833)

Screening

Full-text articles assessed
for eligibility
(n = 20)

Full-text articles excluded
-Duplicated papers n = 2
-Did not assess IGD n = 1
-Review study n = 3
Total n = 6

Eligibility

Studies included for review
(n = 14)

Included

Fig. 11.1 Flow diagram of the study selection process

characteristics and (ii) instrument characteristics. The information extracted concerning the studies' methodological characteristics included: provenience of the sample recruited (i.e., country), sample size, gender distribution, age range (and mean age), sample characteristics, neuroimaging technique used, study aims, and main findings. The information extracted regarding the features of the instruments used to diagnose IGD included: instrument utilized, item sensitivity, criteria included, time scale, theoretical framework, suitability to assess IGD, alignment with the nine IGD criteria, and missing IGD criteria.

11.3 Results

11.3.1 Study Selection

After performing the aforementioned electronic searches, a total of 853 studies (*ProQuest n* = 745; *MEDLINE n* = 108) were initially identified, with the search

performed on the *ProQuest* website yielding the following results: *ProQuest Psychology Journals* $n = 524$; *PsycARTICLES* $n = 115$; *PsycINFO* $n = 106$; *Applied Social Sciences Index and Abstracts* $n = 0$; and *ERIC* $n = 0$. All 853 papers had their titles and abstracts screened, resulting in the exclusion of 833 papers that were of no relevance for the present review. Consequently, a total of 20 studies were eligible for further review. Of these, six papers had to be further excluded because they were either duplicated ($n = 2$), did not assess IGD ($n = 1$), or were review papers ($n = 3$). Following this study selection process, 14 studies were eligible for further analysis as they fully endorsed all inclusion criteria (see Fig. 11.1).

11.3.2 Publication Rate of Peer-Reviewed Neuroimaging Studies on IGD

One of the conditions set by the APA in the DSM-5 was that if IGD is to be recognized as an independent disorder in the future, more studies should be carried out to help ascertain the prevalence rates of IGD across the globe, its clinical course and possible genetic influences, and potential biological factors, based on, for instance, brain imaging data (APA 2013). For this reason, research on IGD employing neuroimaging techniques is of utmost importance not only because of its methodological capabilities, but also because the apparent weight it may carry towards the formal recognition of IGD as an independent disorder in the future [as neurobiological empirical evidence appears to be given more weight than psychological empirical evidence when considering the inclusion of behavioral addictions—such as IGD and sex addiction—in the DSM (Griffiths 2016)]. In light of this, Fig. 11.2 shows a clear trend toward an increase of published peer-reviewed studies on IGD using neuroimaging techniques. This increased trend is most obvious from the period of 2014–2015 because the official diagnosis of IGD only appeared in the scientific literature in May 2013 with the publication of the DSM-5, and because the systematic searches performed for this review were conducted in January 2016.

11.3.3 Neuroimaging of IGD

In order to present some of the latest neuroimaging research on IGD, this section briefly summarizes the main findings of the studies that fully met the inclusion criteria of this review as previously outlined. Ding et al. (2014) found that the prefrontal cortex may be involved in the circuit modulating impulsivity, while its impaired function may be related to high impulsivity in adolescents with IGD, which in turn, may contribute to the IGD process. Sun et al. (2014) concluded that
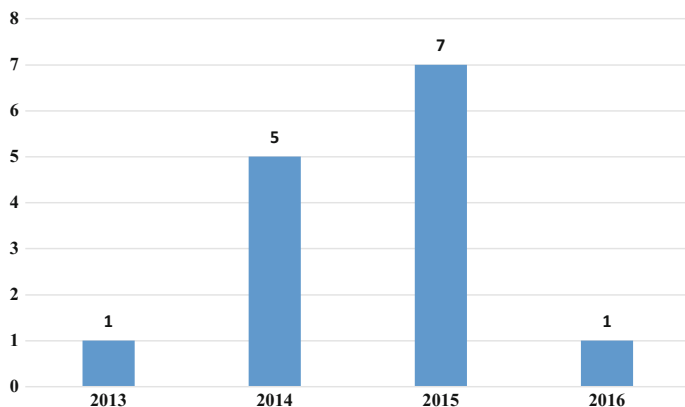
Fig. 11.2 Publication rate of peer-reviewed neuroimaging studies on Internet Gaming Disorder from May 2013 to January 2016. *Note*. This figure only includes studies that met all inclusion criteria of the present systematic review

diffusional kurtosis imaging (DKI) can detect subtle differences in gray matter microstructure between IGD and healthy individuals, and that DKI can provide sensitive imaging biomarkers for assessing the severity of IGD. In the study conducted by Dieter et al. (2015), the authors found that disordered gamers tend to identify significantly more with their avatar in comparison to nondisordered gamers. The authors also noted that the avatar might increasingly replace gamers' ideal self as gaming addiction progresses. Wang et al. (2015a) found that individuals with IGD presented with significant gray matter volume reduction in the bilateral anterior cingulated cortex and other brain regions when compared to healthy individuals. Additionally, IGD was also found to compromise both behavioral and neural structure in adolescents with IGD. Xing et al. (2014) found that the abnormal structural connectivity in the right salience network was associated with impaired executive function in adolescents with IGD, with structural connectivity differences found between IGD adolescents and healthy controls. Yuan et al. (2016) found that differences between individuals with IGD and healthy controls in the striatum volume and frontostriatal circuits resting-state functional connectivity (RSFC) emerged. Additionally, cognitive control deficits detected in IGD were associated with reduced frontostriatal RSFC strength. In addition to these findings, Hahn et al. (2014) concluded that converging evidence for a general reward system deficiency in frequent online gamers exists as frequent players displayed significantly decreased neural activation when anticipating both small and large monetary rewards in the ventral striatum. Luijten et al. (2015) found reduced inhibitory control amongst individuals with IGD but no evidence was found for reduced error processing. Furthermore, attentional control and error processing were mostly intact in IGD individuals. At the molecular level, Tian et al. (2014) found that the D_2 receptor level is significantly associated with glucose metabolism in disordered gamers, indicating that D_2/$5-HT_{2A}$ receptor-mediated dysregulation of

the orbitofrontal cortex could underlie a mechanism for loss of control and compulsive behavior in individuals with IGD. Duven et al. (2015) reported that tolerance effects are present in patients with IGD and noted that the initial orienting toward the gaming reward is suggested to consume more capacity for patients with IGD when compared to healthy controls. Lin et al. (2015b) found that individuals with IGD demonstrated lower low-frequency fluctuation (fALFF) values in superior temporal gyrus and higher fALFF values in the cerebellum. Wang et al. (2015b) found that adolescents with IGD exhibited decreased voxel-mirrored homotopic connectivity (VMHC) between the left and right superior frontal gyrus (orbital part), inferior frontal gyrus (orbital part), middle frontal gyrus and superior frontal gyrus. Son et al. (2015) found that lower absolute beta power can be used as a potential trait marker of IGD. Finally, Yuan et al. (2013) found that adolescents with IGD presented with abnormal amplitude of low-frequency fluctuations in comparison to controls.

In summary, with regard to the functional and structural changes found in IGD individuals when compared to healthy controls, these are often observed within specific brain areas in the frontal lobe (i.e., dorsolateral prefrontal cortex, orbitofrontal cortex, prefrontal gyrus, and the middle frontal gyrus), parietal and temporal lobes (i.e., parahippocampal gyrus), basal ganglia, thalamus, insula and the cerebellum. A finding that mirrors those recently report in similar review studies (Lemos et al. 2014). Furthermore, regardless of the neuroimaging technique utilized, these studies provide preliminary evidence that illustrate converging points and similarities between substance use disorders and IGD, especially during craving processes, a finding that has been previously reported (Smith et al. 2015) and that warrants further investigation as at this point, it may be premature to draw definite conclusions regarding the similarities between IGD and substance use disorders as the definition of IGD currently includes many features present in the definition and diagnostic framework of substance use disorders. Taken together, the main findings reported across all reviewed studies do not provide a complete picture of neuroimaging studies on IGD as other potentially useful findings from similar studies may be missing due to strict inclusion criteria employed in this review.

11.3.4 Methodological Characteristics of Studies

In order to assess some of the methodological features of existing neuroimaging studies examining IGD, key variables were analyzed among the reviewed studies, such as: geographical location of the sample recruited (i.e., country), sample size, gender distribution, age range and mean, sample characteristics, neuroimaging technique used, study aims, and main findings (see Table 11.1).

Regarding the cultural context of the samples recruited, nine studies out of fourteen recruited Chinese samples (Ding et al. 2014; Lin et al. 2015a, b; Sun et al. 2014; Tian et al. 2014; Wang et al. 2015a, b; Xing et al. 2014; Yuan et al. 2013, 2016), three studies used German samples (Dieter et al. 2015; Duven et al. 2015;

Hahn et al. 2014), one study used a Dutch sample (Luijten et al. 2015), and one study used a South Korean sample (Son et al. 2015). As for the sample sizes, studies recruited from a minimum of 26 disordered gamers in one study (Tian et al. 2014) to a maximum of 87 disordered gamers in another study (Yuan et al. 2016). The mean number of disordered gamers recruited across all 14 studies was 43 ($SD = 18.3$). In terms of gender distribution across all studies, only one study had an even split between genders (Ding et al. 2014) while six studies recruited male-only samples (Duven et al. 2015; Hahn et al. 2014; Lin et al. 2015a, b; Luijten et al. 2015; Son et al. 2015; Tian et al. 2014). Although Table 11.1 summarizes the age of gamers recruited, little information was available in the reviewed studies regarding the overall age range of all gamers as the studies usually reported this information only for each group of participants (e.g., experimental and control groups). Despite this limitation, the data gathered suggests that most IGD-affected gamers recruited were in their mid- to late adolescence given the characteristics of the samples recruited across all studies. Almost half of all reviewed studies included gamers that were either addicted to *World of Warcraft* (*WoW*) (i.e., Hahn et al. 2014; Tian et al. 2014; Yuan et al. 2013) or *League of Legends* (*LoL*) (i.e., Xing et al. 2014; Yuan et al. 2016) or included both types of gamers (i.e., participants addicted to *WoW* and participants addicted to *LoL*) (i.e., Dieter et al. 2015) only. The procedure of recruiting participants having problems with only a particular game or specific game genre is questionable because it clearly limits the external validity of the findings reported in such studies as it is unclear to what extent these findings can be replicated across all disordered gamers. Interestingly, all studies provided some form of control group, as well as inclusion, and exclusion criteria in the recruitment of participants, which certainly helped mitigate some of the potential threats to the internal validity of the studies in question.

Finally, as to the neuroimaging techniques used, six studies employed resting-state functional magnetic resonance imaging (rsfMRI) (Hahn et al. 2014; Lin et al. 2015a, b; Wang et al. 2015b; Xing et al. 2014; Yuan et al. 2013, 2016), four studies used functional magnetic resonance imaging (fMRI) (Dieter et al. 2015; Ding et al. 2014; Luijten et al. 2015; Sun et al. 2014), one study used positron emission tomography (PET) (Tian et al. 2014), one study used electroencephalography (EEG) (Duven et al. 2015), one study used resting-state electroencephalography (rsEEG) (Son et al. 2015), and one study used voxel-based morphometry (VBM) (Wang et al. 2015a).

11.3.5 Methodological Characteristics of the Instruments Used to Assess IGD

Table 11.2 provides an overview regarding the preferred methods for diagnosing IGD among the reviewed studies and the features of these instruments and/or diagnostic approaches utilized. Even though the main construct under investigation

Table 11.1 Main methodological characteristics of the studies that met the inclusion criteria

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
Ding et al. (2014)	China	34	50% male	NR;16.41 (3.20)[1]	Adolescents recruited from a mental health center[1]	fMRI	To investigate if different facets of trait impulsivity may be specifically linked to the brain regions characteristic of impaired impulse inhibition in IGD subjects	The prefrontal cortex may be involved in the circuit modulating impulsivity, while its impaired function may relate to high impulsivity in adolescents with IGD, which may contribute directly to the IGD process
Sun et al. (2014)	China	39	83% male[1]	NR; 20.50 (3.55)[1]	Adolescents recruited from a mental health center (i.e., IGD group) and advertisements (i.e., healthy controls)	fMRI	To investigate the utility of diffusional kurtosis imaging (DKI) in the detection of gray matter alterations in people suffering from IGD	DKI can detect subtle differences in gray matter microstructure between IGD and healthy individuals. Additionally, DKI model can provide sensitive imaging biomarkers for assessing the severity of IGD
Dieter et al. (2015)	Germany	32	91% male	NR; 26.72 (6.30)	Adults with IGD recruited through a mental health center and healthy controls	fMRI	To investigate the psychological and neurobiological correlates reflecting the relation of the avatar to	Disordered gamers identify significantly more with their avatar than non-disordered gamers. Additionally,

(continued)

Table 11.1 (continued)

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
					recruited from advertisements		disordered gamers' concepts of their self and ideal self	the avatar might increasingly replace gamers' ideal self as the addiction progresses
Wang et al. (2015a)	China	56	67% male	NR; 18.80 (1.33)[1]	Late adolescent college students	VBM	To investigate the relationship between alteration of gray matter volume and cognitive control feature in adolescents with IGD	Gray matter volume reduction was found in the bilateral anterior cingulate cortex and other brain regions. Additionally, IGD compromised both behavioral activity and neural structure in adolescents with IGD
Xing et al. (2014)	China	34	61% male	NR; 19.10 (0.70)[1]	Adolescents	rsfMRI	To investigate the relationship between the connections within salience network and cognitive control in IGD adolescents	The abnormal structural connectivity in the right salience network was associated with impaired executive function in IGD adolescents. Additionally, structural connectivity differences were found between IGD adolescents and healthy controls

Table 11.1 (continued)

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
Yuan et al. (2016)	China	87	75% male	15-23; 19 (1.40)[1]	Adolescent and young adult university students	rsfMRI	To investigate the differences of striatum volume and resting-state functional connectivity (RSFC) networks in IGD and healthy individuals	Overall findings consistent with the literature on substance use disorders as differences between IGD and healthy controls in the striatum volume and frontostriatal circuits RSFC emerged. Moreover, cognitive control deficits detected in IGD were correlated with reduced frontostriatal RSFC strength
Hahn et al. (2014)	Germany	33	100% male	18-34; 25.50 (4.18)[1]	Adolescent and adult gamers and non-gamers	rsfMRI	To investigate if players of the Massively Multiplayer Online Role-Playing Game World of Warcraft show a generally deficient reward system as in substance use disorders	Converging evidence for a general reward system deficiency in frequent online gamers was found. Frequent players displayed significantly decreased neural activation during the anticipation of both small and large

Table 11.1 (continued)

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
								monetary rewards in the ventral striatum
Luijten et al. (2015)	Netherlands	34	100% male	NR; 20.83 (3.05)[1]	Adolescent and adult gamers and non-gamers	fMRI	To investigate if IGD players are characterized by deficits in various aspects of cognitive control (i.e., inhibitory control, error processing, attentional control)	Reduced inhibitory control amongst IGD players was found while no evidence was found for reduced error processing in IGD players. Furthermore, attentional control and error processing were mostly intact
Tian et al. (2014)	China	26	100% male	NR; 23.50 (2.60)[1]	Adolescent and adult gamers and non-gamers	PET	To examine the post synaptic D_2 receptors and regional brain glucose metabolism in IGD	The D_2 receptor level is significantly associated with glucose metabolism in disordered gamers, indicating that D_2/$5\text{-}HT_{2A}$ receptor-mediated dysregulation of the orbitofrontal cortex could underlie a mechanism for loss of control and compulsive behavior in IGD individuals

(continued)

Table 11.1 (continued)

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
Duven et al. (2015)	Germany	27	100% male	NR; 24.29 (5.84)[1]	Adults with IGD recruited through a mental health center and healthy controls recruited from advertisements	EEG	To investigate whether enhanced motivational attention or tolerance effects are present in patients with IGD	Tolerance effects are present in patients with IGD. Furthermore, the initial orienting toward the gaming reward is suggested to consume more capacity for patients with IGD
Lin et al. (2015a, b)	China	52	100% male	NR; 22.20 (3.13)[1]	Late adolescent and adult college students	rsfMRI	To investigate the abnormal spontaneous brain activity in IGD with the low-frequency fluctuation (fALFF) at different frequency bands	IGD individuals demonstrated lower fALFF values in superior temporal gyrus and higher fALFF values in cerebellum
Wang et al. (2015b)	China	41	76% male	14-17; 16.94 (2.73)[1]	Adolescents with IGD recruited from a mental health center and healthy controls	rsfMRI	To investigate the interhemispheric resting state functional connectivity of the whole brain of adolescents with IGD using a new voxel-mirrored homotopic connectivity (VMHC) method	Adolescents with IGD exhibited decreased VMHC between the left and right superior frontal gyrus (orbital part), inferior frontal gyrus (orbital part), middle frontal gyrus and superior frontal gyrus

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Table 11.1 (continued)

Author	Country	Sample size	Gender distribution (%)	Age range (years) and Mean age (SD)	Sample characteristics	Neuroimaging technique used	Study aims	Main findings
Son et al. (2015)	South Korea	76	100% male	NR; 22.71 (5.47)	Young males diagnosed with IGD (N = 34), alcohol use disorder (N = 17) and 25 healthy controls	rsEEG	To identify the unique neurophysiological characteristics that can be used as biomarkers of IGD	Lower absolute beta power can be used as a potential trait marker of IGD
Yuan et al. (2013)	China	36	66% male	NR; 19,40 (3.10)[1]	Adolescent college students	rsfMRI	To investigate the local features of spontaneous brain activity in adolescents with IGD and healthy controls during resting-state	IGD adolescents presented with abnormal amplitude of low frequency fluctuations in comparison to controls

Superscripts [1]Information concerning the experimental (i.e., disordered gamers) group
Abbreviations fMRI functional magnetic resonance imaging; *VBM* voxel-based morphometry; *rsFMRI* resting-state functional magnetic resonance imaging; *PET* positron emission tomography; *EEG* electroencephalography. *rsEEG* resting-state electroencephalography

of the studies reviewed was IGD, the diagnosis of this disorder was carried out most of the time using measures that were either (i) designed to assess generalized Internet addiction (IA) or (ii) measures that had their theoretical framework based on the concept of IA or non-validated diagnostic criteria. More specifically, in terms of diagnosis of IGD, five studies (i.e., Ding et al. 2014; Sun et al. 2014; Wang et al. 2015a, b; Yuan et al. 2013) used Young's Diagnostic Questionnaire (YDQ) (Young 1998b) with Beard and Wolf's (2001) suggested criteria for IA, two studies (i.e., Lin et al. 2015a, b; Xing et al. 2014) used the Internet Addiction Test (IAT) (Young 1998a), one study (i.e., Luijten et al. 2015) used the Videogame Addiction Test (VAT)[1] (Van Rooij et al. 2012), one study (i.e., Tian et al. 2014) used Tao et al. (2010) diagnostic criteria for IA, one study (i.e., Dieter et al. 2015) used the Checklist for the Assessment of Internet and Computer Game Addiction (AICA-C) (Wölfling et al. 2012), another study (i.e., Duven et al. 2015) used the Scale for the Assessment of Internet and Computer Game Addiction (AICA-S, CSV-S) (Wölfling et al. 2011), and one study (i.e., Hahn et al. 2014) adopted a frequency criterion based on time spent gaming (i.e., playing at least four times per week for one hour or more for at least 1 year). Finally, only two studies (i.e., Son et al. 2015; Yuan et al. 2016) used the DSM-5 criteria for IGD (APA 2013) to diagnose IGD.

Although most studies relied on only one instrument or criterion to diagnose and assess the severity of IGD, five studies, including the two studies that used the IGD criteria to diagnose IGD, adopted two different instruments to diagnose and assess the severity of IGD (Ding et al. 2014; Son et al. 2015; Sun et al. 2014; Wang et al. 2015b; Yuan et al. 2016), with these instruments either being the Chen Internet Addiction Scale (CIAS) (i.e., Ding et al. 2014; Sun et al. 2014; Wang et al. 2015b) or the IAT (i.e., Son et al. 2015; Yuan et al. 2016).

11.4   Discussion

The present chapter sought to systematically review and evaluate some of the methodological and instrument characteristics of the most recent IGD studies that have employed commonly used neuroimaging techniques. In regard to the methodological features assessed in the reviewed studies, data were collected and analyzed concerning the studies' methodological characteristics such as: geographical location of the sample recruited (i.e., country), sample size, gender distribution, age range and mean, sample characteristics, neuroimaging technique used, study aims, and main findings. Additionally, the quality of assessment of IGD amongst neuroimaging studies published after the formulation of the nine IGD criteria in the DSM-5 (APA 2013) was also assessed by examining the following

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[1]Although this test presents with some degree of validity to assess gaming addiction, the theoretical framework of this test was based on Compulsive Internet Use theory derived from the DSM-IV criteria for dependence and obsessive-compulsive disorder and the components model of addiction see van Rooij et al. (2012).

Table 11.2 Main features of the instruments used to assess Internet Gaming Disorder (IGD) in neuroimaging studies

Author	Instrument	Item sensitivity	Criteria covered	Time scale	Theoretical framework	Suitability to assess IGD[1]	Alignment with IGD criteria	Missing IGD criteria
Ding et al. (2014)	Young's Diagnostic Questionnaire (YDQ) modified to reflect Beard and Wolf's (2001) criteria for Internet addiction[2]	Yes/no	Preoccupation; tolerance; inability to control use; withdrawal; salience; jeopardy of opportunities; deception; mood modification	NR	Pathological gambling (DSM-IV)	No	Partial	3, 5, and 6
Sun et al. (2014)	Young's Diagnostic Questionnaire (YDQ) modified to reflect Beard and Wolf's (2001) criteria for Internet addiction[2]	Yes/no	Preoccupation; tolerance; inability to control use; withdrawal; salience; jeopardy of opportunities; deception; mood modification	NR	Pathological gambling (DSM-IV)	No	Partial	3, 5, and 6
Dieter et al. (2015)	Checklist for the Assessment of Internet and Computer game Addiction (AICA-C)	6-point	Craving; tolerance; withdrawal; loss of control; preoccupation; negative consequences	1 month	Internet addiction as a generalized problem including specific usages (e.g., video gaming)	Yes	Partial	5, 6, 7, and 8
Wang et al. (2015a)	Young's Diagnostic Questionnaire (YDQ) modified to reflect Beard and Wolf's (2001) criteria for Internet addiction	Yes/no	Preoccupation; tolerance; inability to control use; withdrawal; salience; jeopardy of opportunities; deception; mood modification	NR	Pathological gambling (DSM-IV)	No	Partial	3, 5, and 6

(continued)

Table 11.2 (continued)

Author	Instrument	Item sensitivity	Criteria covered	Time scale	Theoretical framework	Suitability to assess IGD[1]	Alignment with IGD criteria	Missing IGD criteria
Xing et al. (2014)	Internet Addiction Test (IAT)	6-point	Salience; excessive use; neglect work; anticipation; lack of control; neglect social life	1 month	Pathological gambling (DSM-IV)	No	Partial	2, 5, 6, and 8
Yuan et al. (2016)	IGD criteria (DSM-5)[3]	Yes/no	Preoccupation; withdrawal; tolerance; inability to control use; loss of interest in activities; continued excessive use despite knowledge of problems; deception; escape/mood modification; jeopardy or loss of relationships and opportunities	1 month	Internet Gaming Disorder (DSM-5)	Yes	Total	None
Hahn et al. (2014)	Frequency criteria (i.e., playing at least four times per week for 1 h or more for at least 1 year)	–	Salience	12 months	Excessive playing time is likely to reflect IGD	No	Partial	2, 3, 4, 5, 6, 7, 8, and 9
Luijten et al. (2015)	Videogame Addiction Test (VAT)	5-point	Loss of control, conflict, preoccupation/salience, coping/mood modification, withdrawal	NR	Compulsive internet use theory derived from the DSM-IV criteria for dependence and obsessive-compulsive disorder and the components model of addiction	Yes	Partial	3, 5, 6, 7, and 9

(continued)

Table 11.2 (continued)

Author	Instrument	Item sensitivity	Criteria covered	Time scale	Theoretical framework	Suitability to assess IGD[1]	Alignment with IGD criteria	Missing IGD criteria
Tian et al. (2014)	Diagnostic criteria for Internet addiction by Tao et al. (2010)	NR	Preoccupation; withdrawal; tolerance; lack of control; excessive use despite problems; loss of interests; mood modification	3 month	Impulsive control disorder; pathological gambling (DSM-IV); components model of addiction and substance use disorder	No	Partial	7 and 9
Duven et al. (2015)	Scale for the Assessment of Internet and Computer Game Addiction (AICA-S, CSV-S)	5-point	Excessive use; preoccupation; compulsive use; tolerance; withdrawal; craving; escape; inability to control use; negative consequences	NR	Substance dependence (DSM-IV-TR and ICD-10)	Yes	Partial	2, 5, 6, 7, and 9
Lin et al. (2015a, b)	Internet Addiction Test (IAT)	6-point	Salience; excessive use; neglect work; anticipation; lack of control; neglect social life	1 month	Pathological gambling (DSM-IV)	No	Partial	2, 5, 6, and 8
Wang et al. (2015b)	Young's Diagnostic Questionnaire (YDQ) modified to reflect Beard and Wolf's (2001) criteria for internet addiction[2]	Yes/no	Preoccupation; tolerance; inability to control use; withdrawal; salience; jeopardy of opportunities; deception; mood modification	NR	Pathological gambling (DSM-IV)	No	Partial	3, 5, and 6
Son et al. (2015)	IGD criteria (DSM-5)[3]	Yes/no	Preoccupation; withdrawal; tolerance; inability to control use; loss of interest in	1 month	Internet Gaming Disorder (DSM-5)	Yes	Total	None

(continued)

Table 11.2 (continued)

Author	Instrument	Item sensitivity	Criteria covered	Time scale	Theoretical framework	Suitability to assess IGD[1]	Alignment with IGD criteria	Missing IGD criteria
			activities; continued excessive use despite knowledge of problems; deception; escape/mood modification; jeopardy or loss of relationships and opportunities					
Yuan et al. (2013)	Young's Diagnostic Questionnaire (YDQ) modified to reflect Beard and Wolf's (2001) criteria for Internet addiction	Yes/no	Preoccupation; tolerance; inability to control use; withdrawal; salience; jeopardy of opportunities; deception; mood modification	NR	Pathological gambling (DSM-IV)	No	Partial	3, 5, and 6

Superscript [1]Suitability was evaluated by verification of published peer-reviewed psychometric validation studies investigating the validity and reliability of the instrument to assess IGD. [2]The severity of IGD was assessed with the Chen Internet Addiction Scale (CIAS). [3]The severity of IGD was assessed with the IAT

Abbreviation NR Not reported

Note **IGD criteria (DSM-5; APA** 2013): (1) preoccupation with games; (2) withdrawal symptoms when gaming is taken away; (3) tolerance, resulting in the need to spend increasing amounts of time engaged in games; (4) unsuccessful attempts to control participation in games; (5) loss of interest in previous hobbies and entertainment as a result of, and with the exception of, games; (6) continued excessive use of games despite knowledge of psychosocial problems; (7) deceiving family members, therapists, or others regarding the amount of gaming; (8) use of games to escape or relieve negative moods; and (9) jeopardizing or losing a significant relationship, job, or education or career opportunity because of participation in games

indicators across all reviewed studies: instrument utilized, item sensitivity, criteria covered, time scale, theoretical framework, suitability to assess IGD, alignment with the nine IGD criteria, and missing IGD criteria.

Overall, this chapter provides objective data concerning a trend suggesting an increase in the publication rates of IGD studies using neuroimaging techniques since the publication of the DSM-5 (APA 2013). As shown in Fig. 11.2, the number of such studies is increasing and this may be beneficial to the process of formal recognition of IGD in future editions of the DSM (and other diagnostic manuals). This is because the APA suggested neurobiological evidence for IGD is of utmost importance. However, quantity does not necessarily equate to quality because there are a series of methodological issues that appear to hinder the progress of this type of research. Based on the results found in this review, the following recommendations are made to help improve the overall quality of future studies on IGD using neuroimaging techniques. Some of these recommendations apply to other types of IGD research (e.g., self-report surveys, focus group interviews, experiments, etc.), so implementing such recommendations is advised whenever possible as it may help strengthen the quality of future research into IGD.

Methodological Recommendations

1. Recruitment of gamers (cultural background): Since most of the reviewed studies were carried out in Asian countries, mostly in China, and only few studies were conducted in Western countries, it is recommend that future studies recruit participants from both Western and Eastern regions of the world where both online and offline games are played. This procedure is crucial to improving the quality of research on IGD as replicability of findings across all cultures where gaming is prevalent is important if research is to progress.

2. Recruitment of gamers (gender and age groups): Based on the findings collated in this review, it is also recommended that researchers recruit samples that are balanced in terms of gender and age. It is paramount to recruit gamers from diversified cultural backgrounds, otherwise findings may (potentially) be gender/culture biased or gender/culture-specific, and therefore, less likely to be replicated across different cultural settings.

3. Recruitment of gamers (clinical vs. experimental groups): Although it is common practice to recruit participants seemingly addicted to specific types of games (e.g., *WoW, LoL*, etc.) or game genres (e.g., Massively Multiplayer Online Role Playing Games), as suggested by the findings of this review, this procedure should be avoided as it has been largely adopted in past gaming addiction research from the early 2000s (see Pontes and Griffiths 2014) and is known for being problematic because IGD can occur in any type of gaming (e.g., online and/or offline) and therefore is not limited to a specific type of game and/or genre. Ultimately, limiting the recruitment of IGD-affected individuals to specific games may lead to biased results as other disordered gamers who play other games and genres may be overlooked.

4. Neuroimaging data (use of eclectic techniques): One noticeable finding in this review was that a large number of studies employed rsFMRI in order to collect

imaging data from gamers. Although this may not be problematic in and of itself, authors are advised to adopt an eclectic approach to imaging data collection by using more heterogeneous and other cutting-edge techniques so more information regarding the neurobiological etiology and course of IGD may be acquired. For instance, the combination of fMRI techniques with insights from PET research provides more direct insights into the biochemical mechanism of human behaviors, including IGD (Ko et al. 2015). The adoption of such approaches is likely to lead to quicker recognition of IGD by the psychiatric community as an independent disorder because greater and more diversified data will be available.

5. The inherent potential of using fMRI (refining the diagnostic features of IGD): Due to the need for differentiating chemical and nonchemical addictions coupled with the need to refine the diagnostic features of IGD, studies using fMRI techniques are welcome due to their inherent potential for investigating the specific mechanisms of addiction, including response to a substance, vulnerability for addiction, characteristics or symptoms of addictive behavior, and consequences of addiction (Fowler et al. 2007; Ko et al. 2015). For this reason, neurobiological research into IGD should formulate clear hypotheses derived from previous evidence from brain imaging studies as they might help clarify the utility and appropriateness of having specific diagnostic criteria within the diagnostic framework of IGD. Consequently, this type of research may provide robust evidence to either confirm or disconfirm claims that IGD may arise without associated withdrawal symptoms (Kaptsis et al. 2016) or that the tolerance criterion of IGD might be a prominent characteristic of passionate gaming rather than a criterion indicative of *bona fide* gaming addiction (Kardefelt-Winther 2015).

6. Impacts of IGD on cognition (avoiding premature conclusions): According to Ko et al. (2015), any conclusions regarding cognitive function in IGD would still be premature as the overall effect of IGD on cognitive functioning remains controversial. Contrary to most controlled substances that are known to have damaging effects on the brain, a reasonable assumption is that they impair cognitive function. However, it is known that gaming can exercise and enhance many specific cognitive functions (e.g., Stroud and Whitbourne 2015; Toril et al. 2014). For this reason, the hypothesis that gaming in and of itself produces a deficit in cognitive function is questionable because perfect performance in gaming requires good cognitive function (Ko et al. 2015). Thus, studies reporting potentially negative impacts of IGD on cognition should take into account the fact that gaming may also produce positive cognitive effects on gamers.

Assessment of IGD recommendations

7. Assessment of IGD (key assessment issues): As shown in Table 11.2, although all studies reviewed concerned the phenomenon of IGD, the diagnosis of this potential disorder was largely conducted by employing assessment instruments

that were either (i) designed to assess generalized IA or (ii) had their theoretical framework based on the concept of IA or (iii) nonvalidated diagnostic criteria. This is perhaps one of the most troublesome findings of this review because the use of different, nonspecific, and/or psychometrically weak tools to assess IGD not only represents a threat to the call for unification in the assessment of IGD (Griffiths et al. 2015, 2016), but also hinders the progress of research in this field as cross-cultural comparisons between studies are virtually impossible to be achieved under such circumstances (Kuss et al. 2014). Moreover, researchers in the field are discouraged to adopt such procedures because they severely compromise the overall validity of neuroimaging studies on IGD since the main construct under investigation is not being properly assessed but instead, other related (and yet different) constructs are being assessed (i.e., generalized IA rather than IGD).

8. Assessment of IGD (frequency of gameplay and IGD): Although it is not common practice to assess IGD based on frequency of gameplay (i.e., time spent gaming), there are still studies using the frequency criterion as a way to diagnosing IGD cases. It has now been long established in the field that excessive gaming does not necessarily equate to addiction (Griffiths 2010; Kuss et al. 2012) and that there is a difference between engaged and addicted gamers (see Charlton and Danforth 2007; Fuster et al. 2015; Pontes et al. 2014). Therefore, we encourage authors to assess and diagnose IGD based on newly developed standardized instruments available that were devised using the updated framework to assess IGD (i.e., the APA's nine criteria) and that have been shown to possess acceptable levels of validity and reliability (such as: Király et al. 2015a, b; Lemmens et al. 2015; Pontes and Griffiths 2015a; Pontes et al. 2014). By adopting such a recommendation, the goal of unification in the assessment of IGD will be more tangible and less difficult to achieve.

9. Assessment of IGD (heterogeneity issues): A systematic review conducted by King and colleagues (2013) assessing a total of 18 problematic gaming instruments across 63 empirical studies, demonstrated that most tools presented similar limitations including: (i) inconsistent coverage of core addiction indicators, (ii) use of varying cut-off scores to indicate clinical status, (iii) lack of a temporal dimension, (iv) untested or inconsistent dimensionality, and (v) inadequate data on predictive validity and inter-rater reliability. Similarly, the findings of the present chapter mirrored those found by King and colleagues (King et al. 2013). More specifically, the present review found that the included studies used eight different methods for diagnosing IGD, which suggests great disparity and heterogeneity between the preferred methods for assessing IGD in this new era of research. As noted above, there are valid and reliable psychometric tools designed to assess IGD based on the APA's suggested framework and these should be used. Because of the inherent difficulties in obtaining a gold standard for IGD across studies, authors can mitigate the possible biases stemming from the assessment of this disorder by adopting commonly used tools that assess IGD using APA criteria and possess some degree of validity and reliability. This is an important aspect of research into IGD more generally

(as shown in Table 11.2) because most instruments used to assess IGD are based on theoretical frameworks of IA that lack content validity to assess IGD because many important aspects of the IGD construct are not fully covered.

10. Assessment of IGD (diagnosis vs. severity): Findings in this chapter also found that most of the studies reviewed relied on one instrument or criterion to diagnose IGD and another one to assess the severity of IGD. More specifically, five studies, including the two studies that have used the IGD criteria to diagnose IGD, adopted two different instruments to diagnose and assess the severity of IGD (Ding et al. 2014; Son et al. 2015; Sun et al. 2014; Wang et al. 2015b; Yuan et al. 2016), with these instruments either being the CIAS (i.e., Ding et al. 2014; Sun et al. 2014; Wang et al. 2015b) or the IAT (i.e., Son et al. 2015; Yuan et al. 2016). Although it is not entirely clear as to why two different instruments were used to diagnose and assess the severity of IGD, this certainly does not facilitate a sound assessment of IGD as more noise is introduced into such studies with the use of different assessment tools. Additionally, and perhaps more worryingly, assessing the severity of IGD with generalized IA is not the way forward as issues of construct validity may emerge. Hence, it is recommended to use one of the newly standardized psychometric tools to assess the severity of IGD as well as an initial structured interview to diagnose IGD based on the nine IGD criteria if necessary as they appear to have clinical validity (Ko et al. 2014).

Based on the findings raised and highlighted in this chapter (and the recommendations generated upon them), it is hoped that future IGD studies, especially those using neuroimaging techniques, may improve their methodological and instrumentation features as there are several different ways to overcome such shortcomings that most of the extant studies on IGD using neuroimaging techniques present with.

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