Internet and Video Game Addictions

Diagnosis, Epidemiology, and Neurobiology

Clifford J. Sussman, MD[a,b,*], James M. Harper, MD[c,d], Jessica L. Stahl, MD[e], Paul Weigle, MD[f]

KEYWORDS

• Internet gaming disorder • IGD • Video game • Internet • Addiction • Digital • Computer

KEY POINTS

- Proposed criteria for diagnosis of Internet gaming disorder and other digital technology addictions are analogous to those for substance use or gambling disorders.
- Diagnosis of Internet and video game addictions should include both screening tools and clinical interview for "red flags," such as academic decline, sleep disruption, and changes in real-life activities and relationships.
- Epidemiologic studies, limited by variation in diagnostic methods, yield prevalence estimates ranging from less than 1.0% to 26.8%.
- Internet and video game addictions are associated with psychological and social comorbidities, such as depression, attention-deficit/hyperactivity disorder, alcohol use, anxiety, and poor psychosocial support.
- Neurobiological evidence suggests a dual processing model of digital technology addictions characterized by an imbalance between the reactive reward system and the reflective reward system.

INTRODUCTION

With the increasing power and accessibility to digital technology and exploding range of online activities over the past 2 decades has come a great expansion of the amount of

Disclosure Statement: The authors have no disclosures.

[a] Private Practice, 5410 Connecticut Avenue, Northwest, Suite 112, Washington, DC 20015, USA; [b] Department of Psychiatry, George Washington University Medical School, 2300 I Street NW, Washington, DC 20052, USA; [c] Adolescent Inpatient Psychiatric Unit, Dominion Hospital, 2960 Sleepy Hollow Road, Falls Church, VA 22044, USA; [d] Private Practice, Columbia Associates in Psychiatry, 2501 North Glebe Road, Suite 303, Arlington, VA 22207, USA; [e] Pediatric Nephrology, University of Washington, MS OC.9.820, PO Box 5371, Seattle, WA 98145-5005, USA; [f] Department of Psychiatry, Natchaug Hospital, Hartford Healthcare, 189 Storrs Road, Mansfield Center, Mansfield, CT 06250, USA

* Corresponding author. 5410 Connecticut Avenue Northwest, Suite 112, Washington, DC 20015.

E-mail address: cliffordsussmanmd@gmail.com

Child Adolesc Psychiatric Clin N Am ■ (2017) ■–■
https://doi.org/10.1016/j.chc.2017.11.015 **childpsych.theclinics.com**

time youth regularly spend engaging with it. The 2015 Common Sense Media Use Census found that teens ages 13 to 18 spent a daily average of more than 6.5 hours on screen entertainment (including TV, smart phones, computers, video games, streaming videos, and so forth) and the daily average of tweens ages 8 to 12 was more than 4.5 hours.[1] This represents a significant increase in youth screen habits, with a substantial minority developing excessive, problematic habits that interfere with functioning in work, academics, relationships, and other domains. The concept that it is possible to develop a behavioral addiction to the Internet was first proposed in the 1990s,[2] and interest in this topic has grown along with the influence of the Internet in our lives.

Numerous researchers have investigated Internet and video game addictions ("IVGA" for the remainder of this article) in the past decade.[3–6] A wide variety of online activities are engaging enough to be potentially addictive, including video games, social media, smartphone use, texting, streaming videos, and online pornography. Notably, we omitted online gambling, as its related addiction is typically classified as a subtype of gambling disorder. The subtype of IVGA that research has validated most is video game addiction, particularly to games played online, such as massively multiplayer online games (MMORPGs). Increased acceptance of video game addiction led the 2013 inclusion of "Internet gaming disorder" (IGD) in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-V) as a "condition for further study."[7] A growing body of evidence indicates commonalities between IVGA, including IGD, and more well-established addictions, including substance use disorders and gambling disorder. This paper provides an updated review of IVGA, focusing on the significant body of research published in the 4 years since the proposal of IGD. We explore diagnosis, epidemiology, and neurobiology, much of which overlaps substantially with that of substance use disorders. This article will help clinicians improve their awareness, understanding, and ability to diagnose IVGA.

DIAGNOSIS OF INTERNET GAMING DISORDER AND OTHER TYPES OF INTERNET AND VIDEO GAME ADDICTIONS

Behavioral addictions may be conceptualized as an excessive, uncontrollable, "repeated behavior leading to significant harm or distress."[8] Young[2] initially conceptualized Internet addiction in 1996 using criteria adapted from those of pathologic gambling, the only behavioral addiction recognized in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*. Those meeting criteria had extreme online habits causing academic, occupational, relationship, and/or financial dysfunction.[2] Young's[2] original diagnostic questions served as a basis for many subsequent rating scales and proposed criteria for IVGA.

Most studies of IVGA use similar criteria, based on a conversion of DSM criteria or a well-validated scale for diagnosing substance use disorder or pathologic gambling. Resultant IVGA assessment scales and diagnostic criteria have been adapted for specific subtypes, including addiction to online gaming, the Internet in general, smartphones, online pornography, and others.[9–16] Griffiths'[17] similar conceptualization of addiction, based on the key components of salience, mood modification, tolerance, withdrawal, conflict, and relapse, forms the basis for a number of IVGA assessment scales as well.[18–22]

Romano and colleagues[23] demonstrated that Internet addicts are more likely than nonaddicts to experience withdrawal symptoms following a brief 15-minute Internet exposure. A pronounced decline in mood prompted addicts to rapidly reengage with the Internet. Addicts were also more likely to have depressive, impulsive, and autistic traits.

In 2013, the American Psychological Association proposed IGD, a type of IVGA related exclusively to online video game play, in the DSM-V as a "condition requiring further study" using comparable criteria (**Box 1**).[7]

These IGD criteria are nearly identical to those of the DSM-V's substance use disorder and gambling disorder, although the threshold for IGD is significantly higher. In addition to persistent use leading to distress or impairment, substance use disorder requires only 2 of 11 additional symptoms for diagnosis. Pathologic gambling requires 4 of 9, whereas IGD requires 5 of 9. IGD concerns only addiction to online video gaming, and excludes that of other potentially addictive screen habits included in IVGA. The DSM-V IGD criteria as written are stricter than most definitions of IVGA, and therefore yield lower prevalence rates, more reflective of moderate to severe addiction than a mild addiction or "at-risk" habit, as outlined later in this article.

Other studies of IVGA that were not limited to Internet gaming also validated the resultant loss of function and detrimental outcomes for the affected individual (eg, distress, withdrawal, tolerance, lying, and conflict resulting from use), as well as other symptoms, such as preoccupation and using the Internet to escape negative feelings.[24,25] When evaluating a case of possible IVGA in a patient who does not engage

Box 1
***Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* proposed criteria for Internet gaming disorder as a condition for further study**

Persistent and recurrent use of the Internet to engage in games, often with other players, leading to clinically significant impairment or distress, as indicated by 5 (or more) of the following in a 12-month period:

1. Preoccupation with Internet games. (The individual thinks about previous gaming activity or anticipates playing the next game; Internet gaming becomes the dominant activity in daily life.)
   Note: This disorder is distinct from Internet gambling, which is included under gambling disorder.
2. Withdrawal symptoms when Internet gaming is taken away. (These symptoms are typically described as irritability, anxiety, or sadness, but there are no physical signs of pharmacologic withdrawal.)
3. Tolerance—the need to spend increasing amounts of time engaged in Internet games.
4. Unsuccessful attempts to control the participation in Internet games.
5. Loss of interest in previous hobbies and entertainment as a result of, and with the exception of, Internet games.
6. Continued excessive use of Internet games despite knowledge of psychosocial problems.
7. Has deceived family members, therapists, or others regarding the amount of Internet gaming.
8. Use of Internet games to escape or relieve a negative mood (eg, feelings of helplessness, guilt, anxiety).
9. Has jeopardized or lost a significant relationship, job, or educational or career opportunity because of participation in Internet games.
   Note: Only nongambling Internet games are included in this disorder. Use of the Internet for required activities in a business or profession is not included; nor is the disorder intended to include other recreational or social Internet use. Similarly, sexual Internet sites are excluded.

Specify current severity:
Internet gaming disorder can be mild, moderate, or severe depending on the degree of disruption of normal activities. Individuals with less severe Internet gaming disorder may exhibit fewer symptoms and less disruption of their lives. Those with severe Internet gaming disorder will have more hours spent on the computer and more severe loss of relationships or career or school opportunities.

From American Psychiatric Association. Diagnostic and statistical manual of mental disorders, fifth edition. Arlington (VA): American Psychiatric Publishing; 2013; with permission.

in Internet gaming, it is feasible, if not yet fully validated, to use the criteria in **Box 1** by substituting the name of the online habit, such as "social media," in place of the words "internet games" and "internet gaming."

CLINICAL CONSIDERATIONS IN ASSESSING FOR INTERNET AND VIDEO GAME ADDICTION

Moreno and colleagues[26] recently developed a brief screening tool for clinical diagnosis of IVGA in teens and young adults, which showed 100% sensitivity, although only 59% specificity. A positive screen indicates the need for a more thorough investigation to make or rule out an IVGA diagnosis. Use of this tool enables increased recognition of IVGAs in clinical practice. Their 3-item screen assesses the degree (scored on a 0–4-point scale for each item) that an individual

1. Experiences social anxiety related to a preference for Internet use to the exclusion of real-life relationships
2. Feels withdrawal when not using the Internet
3. Loses motivation to do other things that need to get done because of the Internet[26]

A more detailed screening would then be indicated if a subject's total score was 3 or more.

When performing a psychiatric assessment, it is essential to take a thorough media history (See Nicholas Carson and colleagues' article, "Assessment of Digital Media Use in the Adolescent Psychiatric Evaluation," in this issue).[27] The clinician must obtain a thorough collateral history from a parent or caregiver, as well as the young patient, to properly do so. This includes assessing time spent online, which teens may minimize in their reporting, neglecting to share that while ostensibly sleeping or doing homework on a computer they are actually engaging in online entertainment or social interaction. When assessing children and adolescents for IVGA, it is important to include the extent to which online activities are supervised by parents, where in the home they take place (ie, in a public area vs in the bedroom), what rules address technology use, to what extent conflicts arise regarding screen use, and whether academic performance has been impacted by screen habits.[28] Getting accurate information about screen habits directly from young adult patients living away from home may be more challenging, but focusing on academic or work performance, sleep quantity and quality, as well as "real-life" activities and relationships often provides insight into the influence of online habits on overall functioning. The clinician may elicit various other "red flags" that warrant further evaluation for IVGA. Reduced total sleep time, delay in sleep onset, decreased quality of sleep, and excessive daytime sleepiness lacking a clear cause could each point toward IVGA, as excessive time online often displaces and disrupts needed sleep.[9,10,29] A patient with few "real-life" interactions with friends, as most of his or her social connections are online, may also suffer from IVGA. However, many children and teens do not distinguish between real and virtual friends unless asked specifically to do so, as it has become more normative for most social interactions to occur online or via text.

EPIDEMIOLOGY OF INTERNET AND VIDEO GAME ADDICTION

The exact prevalence of IVGAs is difficult to assess. A lack of standard criteria for diagnosis of IVGA contributes to a substantial variability in population statistics. Prevalence may vary significantly by age, but many studies neglect to distinguish child, adolescent, and adult populations. The matter is further complicated by regional and cultural variability in online habits.

A recent review of cross-sectional and longitudinal studies of IVGA noted use of a variety of diagnostic instruments, as well as use of different cutoff values among studies using the same tool.[30] Mean prevalence estimates from that review and others like it reflect a wide range as well as regional diversity, as shown in **Fig. 1**.[30–39] Prevalence estimates of IGD, also displayed later in this article, indicate a narrower range, although regional divergence remains evident. In both IGD and IVGA, prevalence in Asia is generally higher than in North American or European studies.

It is notable that in studies that distinguish "high" or "definite" IVGA from "low" or "probable" IVGA, the lower prevalence of the former more closely matches that found in IGD, as seen in **Fig. 2**.[40–43]

In diagnosing IGD and other IVGAs, the requirement of clinically significant distress or impairment (or lack thereof) also creates estimate variations. One 2017 study including data from the United States, Canada, the United Kingdom, and Germany indicated a prevalence of 0.5% to 1.0% for those meeting full criteria for IGD, and an overall prevalence of 2.4% for those with "potentially dysfunctional gaming," defined as reporting at least 5 of 9 IGD criteria without related distress or impairment.[44] Similarly, a meta-analysis in 2011 found a significantly smaller mean video game addiction prevalence among studies that required functional impairment for diagnosis, compared with those studies that did not.[43] These differences reaffirm that further study is needed to establish standardized criteria before a more accurate prevalence is established.

The longitudinal stability of IVGA is unclear. Multiple studies demonstrate high rates of independent remission over 1 to 2 years.[30,45,46] One study from Hong Kong reported 46% of those with IVGA remitted after 1 year without intervention. Significant variability exists, however. A study of video game addiction in elementary age youth found a 2-year remission rate of only 15%.[47] The stability of IGD has not yet been investigated, to our knowledge.

RISK FACTORS AND COMORBIDITIES OF INTERNET AND VIDEO GAME ADDICTION

Conceptual models explain how an individual's biological and psychological characteristics interact with addictive features of digital technologies to result in IVGA. For

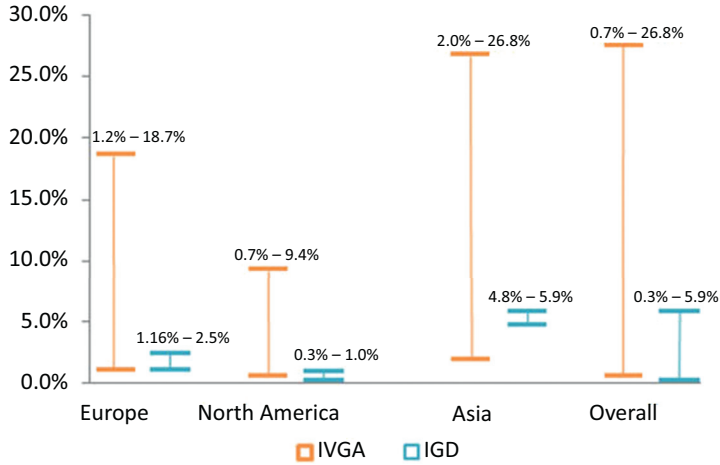

Fig. 1. Range of reported mean prevalence of IVGA and IGD by region.

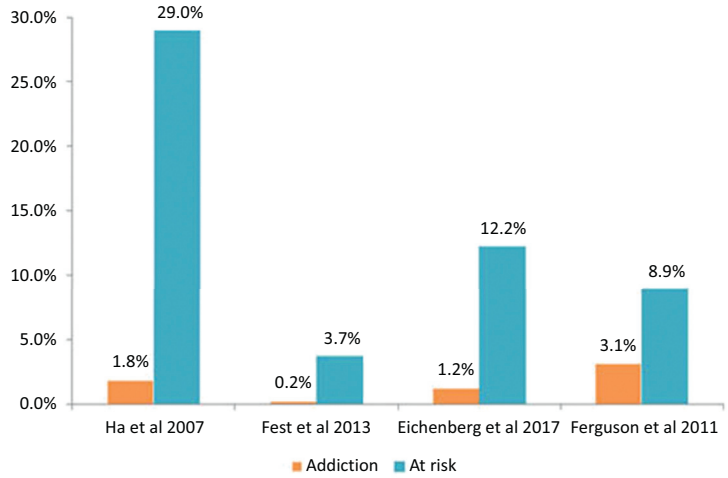

Fig. 2. Prevalence of IVGA categorized as "addicted" versus "at-risk."

example, one addictive aspect of the Internet may be the ability to represent oneself online in an idealized manner, whether by filtering aspects of one's self-representation on social media, or projecting a completely different self-image in the form of an individualized character or "avatar" in an online role playing game (RPG).[48–51] Another addictive factor of many online activities appears to be the incorporation of variable ratio reinforcement, a powerful method of operant conditioning.[50] These concepts, and others like them, need further empirical research for refinement or validation.[51] For clinical purposes, it will be useful for mental health professionals to recognize which features of digital technology draw individuals into addictive patterns of behavior, and to identify characteristics that may make an individual more susceptible to IVGA.

ADDICTIVE FEATURES OF VIDEO GAMES

RPGs, including massive multiplayer online RPGs (MMORPGs, or MMOs) are the game type most consistently related to IVGA, followed by "shooters," multiplayer online battle arena games, and real-time strategy games.[52–55] MMORPGs combine an especially potent mix of factors that makes players particularly vulnerable to developing IGD. These factors include escapism, socialization, competition, and "grinding," the process of perpetually "leveling up" or improving one's gaming character by accumulating in-game achievements and rewards. Together these elements may be synergistically habit forming.[56]

Another factor predisposing one to addictive play is an individual's sensitivity to environmental cues as well as perception of time relative to reward processing. Time cues within games are typically distinct from real-world cues. For example, players from vastly different time zones participate simultaneously in online games with day and night cycles that occur on a schedule unrelated to the physical world. Players become so focused on the constant, immediate feedback to their in-game actions that they become immersed in the game world and are less likely to respond to real-world cues.[57,58] Such players typically ignore real-world cues to stop playing (such as fatigue, social cues, or time of day), leading to excessive gaming times that encroach onto real-world responsibilities.

PSYCHOSOCIAL RISK FACTORS

Personal factors can also affect the likelihood of developing IVGA. Evidence suggests that individuals with social inhibitions or deficits tend to find online communication preferable to in-person interaction, possibly due to reduced risk of direct social confrontation or ability to follow "scripted" conversations focused on common themes.[59–61] Another individual factor that can lead to IVGA is the "fear of missing out" (FOMO). This occurs when the normative drive to be included and engaged in the social group is distorted by the perpetual 24/7 possibility of connections with peers (on social media sites, via text messages between friends, or in an online game). The individual with FOMO is anxiously compelled to excessively check these sources (to the detriment of offline endeavors) for fear of marginalization.[62,63] Other prosocial drives, including maintaining one's status in an online game or reputation within social groups that communicate online, may also contribute to IVGA.[64]

IVGA is particularly prevalent in individuals with a novelty-seeking personality trait, as online entertainment offers a combination of escapism and immediate and repeated reward gratification.[65] IVGA is also prevalent in those with the harm-avoidant personality trait, as online environments create a physically safe, anonymous space, detached from the risks of "real life."[21,40,65] Individuals with insecure, ambivalent, or anxious attachments are also especially vulnerable to developing IVGAs, possibly because they use online entertainment as a vehicle for escapism or immediate social gratification.[42,66,67] One study demonstrated lower rates of IVGA remission among individuals possessing comorbid Cluster B personality traits.[61] This may be because digital technology helps these individuals escape negative emotions, engage in dramatic self-presentation, or act out antisocial impulses in a relatively safe environment.[61]

Poor family support, poor family relationships, high family conflict, and poor psychosocial support are also disproportionally common in youth with IVGA.[37,46,68–70] Poor parent mental health is related to more severe IVGA.[71] Conversely, increasing parental involvement and social support is related to less severe IVGA.[32,72] Poor academic performance and less protective parenting style (as identified using subscales of the Parental Bonding Instrument) have been shown to be independent predictors for Internet addiction, even after controlling for family function (as measured by the "APGAR" instrument), autism, and attention-deficit/hyperactivity disorder (ADHD).[28]

Although many studies note a male predominance for IVGA[28,31,73–75] and IGD,[73,76] other studies find no significant gender differences[34,44,77]:

- Male individuals are more likely than female individuals to develop IVGA related to computer gaming.[33]
- Female individuals are more likely than male individuals to develop IVGA related to smart phone use or social networking,[75,78] and tend to have more psychiatric comorbidities.[79]

The following are other psychosocial risk factors found on reviewing the literature:

- Frequent, short-duration smartphone usage, including games and multiple applications, is highly correlated with IVGA.[34,80]
- Multiple studies agree that individuals with sleep disturbances are more likely to have IVGA.[81–83]
- Aggression,[84] poor social adjustment,[28] avoidant behaviors,[39] low empathy,[85] poor school performance,[32,47] student status,[52] and cyberbullying[86,87] all correlate with IVGA.
- Active religious practice is inversely correlated with IVGA.[88]

PSYCHIATRIC COMORBIDITIES

A number of psychiatric disorders are often comorbid with IVGA and IGD, although limited data exist to inform the causal relationship of these associations. A recent study of 330 Korean middle school students identified psychiatric comorbidity in 20% of those with IGD.[89]

- Depressive disorders: The most frequent comorbid disorders with IGD and IVGA in clinical studies are depressive disorders, such as dysthymia and major depressive disorder.[70,77–79,90–96] One study indicated that IVGA at baseline predicted new-onset depression 2 years later.[47] The relationship of IVGA to suicidal behavior is unclear. One study in adults found an association between IVGA and "suicide planning."[93] Conversely, a study of Turkish adolescents found no relationship between IVGA and suicide risk.[97]
- ADHD, impulsivity, and autism spectrum disorders (ASD): Higher general rates of IVGA have been found in those with ADHD.[28,81,98,99] One study found that 22% of patients with ADHD also suffer from IVGA.[98] Trait impulsivity is positively correlated with IVGA and 11% of those with IGD are impulsive.[76,100] Another study found that trait impulsivity at baseline predicted new-onset video game addiction 2 years later.[47] A final study found that the prevalence of IVGA in adolescents with comorbid ASD and ADHD was 20%, nearly twice that found in teens with either ASD (11%) or ADHD (13%) alone.[101]
- Bipolar disorder: Comorbidity of bipolar disorder with IVGA has been reported in multiple studies.[79,102] Rates of bipolar disorder have been found to be as high as 31% in those with IVGA, as compared with 6% in those with "excessive Internet use." Those with co-occurring IVGA and bipolar disorders are more likely to suffer comorbid substance use, conduct, and personality disorders, although these associations may be more related to bipolar diagnosis than IVGA.[102]
- Alcohol use: IVGA has been positively associated with alcohol use in multiple studies.[75,77,82,103] One study found a rate of alcohol abuse in those suffering IVGA of 13%.[98] Another discovered that adolescents with IVGA are significantly more likely to have problematic alcohol use (16%) than their peers without IVGA (5%).[77]
- Anxiety: Several studies have shown a positive correlation between IVGA and anxiety disorders.[24,76,78,79,91,93] Prevalence rates of IVGA in anxious youth has been reported as low as 9%[75] and as high as 23%.[98] A longitudinal study indicated that IVGA at baseline predicted new-onset social anxiety 2 years later.[47]
- Obsessive-compulsive disorder (OCD): In adults, OCD has been associated with IVGA.[78]
- Alexithymia: This inability to identify emotions in the self has been identified in up to 27% of adults with IVGA.[104] Rates are particularly increased in female individuals with a history of trauma and IVGA.[105]
- Trauma: Adolescents with a history of sexual abuse appear to be at greater risk of IVGA. One study found an IVGA prevalence of 44% in teens with such a trauma history compared with 33% in those without.[106]

NEUROBIOLOGY OF INTERNET AND VIDEO GAME ADDICTION

Importance of a Neurobiological Addiction Model

Advances in understanding reward circuitry of the brain have paved the way for a theory that has changed how many view addiction: the afflicted is addicted not to a specific substance or activity, but to the associated brain response.[105] Therefore, neurobiological similarities with commonly accepted addictions add further credibility to IVGA. Although

substances of abuse and stimulating digital technology differ in how the input is received by the brain, both appear to stimulate a common pathway by which pleasure is experienced, reinforced, and regulated: the mesocorticolimbic dopamine system.[105–109] Dysfunction within this area is expected in all substance use disorders and behavioral addictions. A search of the international literature reveals a growing amount of research on the neurobiology of IVGA, using structural and functional imaging, electroencephalogram (EEG), and genetics. Here we review these studies to establish whether patterns of neurobiological functioning in IVGA resemble those found in substance use disorders, particularly in brain pathways involved in addiction.

The Dual Processing Model

One of the most comprehensive of established neurobiological models explaining how addictive behavior relates to dysfunction within the brain is the dual processing model. This paradigm describes addiction as an imbalance between the "go" network and the "stop" network.[110–113] The go network, also called the reactive system (RaS), mediates immediate outcomes from behavior. The stop network, also called the reflective system (RfS), provides inhibitory control based on long-term projections[114,115] (**Fig. 3**). Key structures involved in the go network are the bottom-up mesolimbic and mesocortical dopamine pathways (including the nucleus accumbens), other parts of the striatum, and the amygdala. Along the top of these pathways are key structures of the stop network, areas associated with control of impulses and attention, such as the ventromedial, dorsolateral, and anterior cingulate prefrontal cortices. Other vital stop network structures are associated with memory and affective states, such as

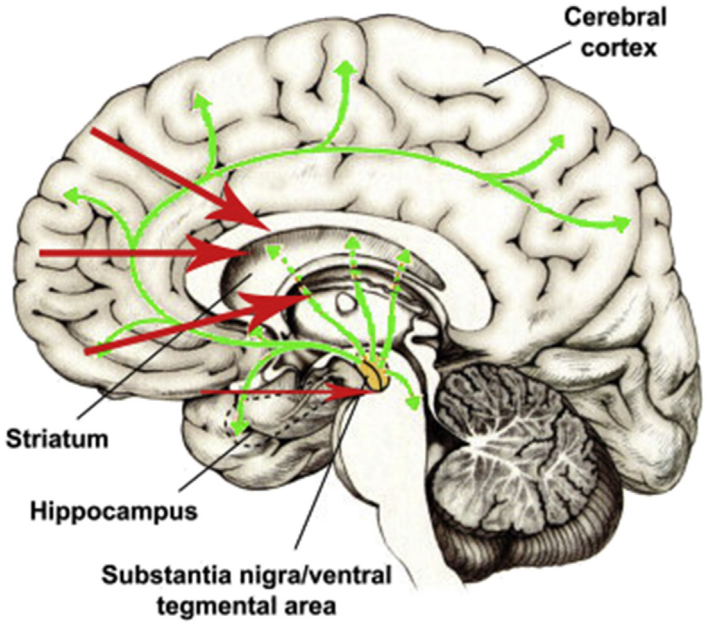

Fig. 3. Dual processing reward system model. The green arrows show the direction of the bottom-up "go" network (reactive) and the red arrows show the direction of the top-down "stop" network (reflective). An imbalance between these 2 systems is implicated in addiction. (*Adapted from* Dalley JW, Roiser JP. Dopamine, serotonin and impulsivity. Neuroscience 2012;215:46; with permission.)

the somatosensory cortex, the insula, and the hippocampus.[115] The dual processing model allows clinicians to understand addiction as an imbalance of 2 competing forces, which parallels the ambivalence that patients with addictions typically display. A stronger go network and weaker stop network have been found in patients with substance use disorders (SUDs) as well as ADHD. The adolescent brain has imbalance between the go and stop networks when compared with that of the adult brain, which may help explain why the onset of SUDs and IVGA often occurs in adolescence.[110]

The Go Network: Stimulation Seeking in Internet and Video Game Addiction

The "go" network, or RaS, is a bottom-up process involving the release of dopamine along the mesocorticolimbic dopaminergic pathway. Dopamine-agonist medication, often used to treat Parkinson disease, can stimulate the go network, causing addictive behaviors, such as gambling, binge eating, and hyper-sexuality.[116] Video gaming has been shown to cause dopamine release in the nucleus accumbens, the brain region that mediates pleasure, which is similar in magnitude to those created by recreational drug abuse.[116,117] Animal models have shown that the extent of dopamine release in this area is inversely related to the time between the initiating behavior and receipt of the reward. Therefore, the "rush" of dopamine release from using digital technology or drugs of abuse is related not only to the magnitude of reward received, but how quickly that reward is experienced.[118] This relationship becomes more relevant as digital technology evolves to be more immediately gratifying, more sophisticated applications and games are designed, solid state hard drives process ever faster, and Internet connections become more rapid. Through prolonged, excessive exposure to immediate rewards granted by engaging with video games and other digital entertainment, eventual downregulation of dopamine and glutamate receptors in the nucleus accumbens can occur, leading to tolerance, withdrawal, and compulsive stimulation seeking.[119–121]

Recent imaging studies demonstrate that go system changes occur in IVGA.[120] Researchers have found that patients with IGD have increased volumes of the caudate nucleus and nucleus accumbens, especially in the most severe cases.[121] PET scan studies indicate that excessive video game play is associated with downregulation of striatal dopamine receptors.[122,123] Patients with IVGA, including excessive "World of Warcraft" players, have been found to have a reward deficiency characterized by lower dopamine receptor density in these areas and lower physiologic responsiveness to rewards that are not game-related.[124] A recent study showed greater addictive behaviors in rats with genetic polymorphisms leading to decreased dopamine receptor density along the mesocorticolimbic pathway.[112] A similar study in human subjects found that excessive gamers with similar polymorphisms scored higher on a scale of reward dependence, a trait associated with addiction, than excessive gamers lacking these polymorphisms.[125]

Each of these studies suggests that the downregulation of dopamine receptors plays a key role in the pathology of IVGA, similar to that of SUDs.[126] Although SUD studies suggest that dopaminergic downregulation is reversible, estimates of recovery time vary widely.[127,128] It would be useful for providers to know whether dopaminergic downregulation is also reversible in IVGA, and if so, how long it takes. However, no applicable studies in IVGA could be found by these authors. Therefore, this area of clinical concern would benefit from research.

Prolonged stimulation of the go network and the resulting interaction between the amygdala and hippocampus leads to craving, which is often triggered by conditioned cues.[119] Functional MRI (fMRI) studies of addicts experiencing cue-induced cravings for video game play or pornography showed activation in these regions and throughout the mesocorticolimbic pathway (Gola and colleagues, 2017).[116,129–131] EEG research has shown

that game-related cues occupy more attentional capacity in individuals with IGD than control groups.[54] These studies also parallel findings of similar processes in SUD.

The Stop Network: Impulsivity in Internet and Video Game Addiction

The "stop" network, or RfS, is a top-down process that inhibits the go network via glutamatergic pathways along the mesocorticolimbic regions, starting in the prefrontal cortex.[114,132] The stop network plays a major role in our ability to consciously resist impulses. Subjects with impairment within the stop network are more likely to be motivated by short-term versus long-term goals, compared with the general population.[107,133]

A 2014 meta-analysis of fMRI studies demonstrated that IGD is related to increased activation of known inhibitory, executive functioning, and working memory pathways in the prefrontal cortex, some of which increased along with time spent gaming. The investigators noted that this result, combined this with those of previous research, indicate a failure of self-regulatory processes in those with IGD.[134] A combined MRI and fMRI study found that patients with more severe Internet addiction have reduced gray matter in the right frontal pole, an area with increased functional connectivity to the left ventral striatum, resulting in "higher activation of the ventral striatum at rest." These investigators suggest that Internet addicts have reduced "ability to maintain long-term goals in face of distraction" due to diminished activity of the stop network. Another morphometry study demonstrated that patients with online gaming addiction have reduced gray and white matter integrity in the orbitofrontal and prefrontal cortex, areas integral to the stop network.[135] A genetic study found a target gene that modulates myelination in specific areas associated with the stop network (ie, the right frontal tracts and left cingulate gyrus, as well as the thalamus) to be protective against IGD.[136] In summary, imaging studies show that stop network regions, regulating impulse control and executive function, appear to be involved in regulating online habits, giving further weight to the dual processing model.

Numerous studies have explored the relationship between IVGA and impulsivity, using neurocognitive testing such as the Stroop test, go/no-go tasks, and delay discounting, often in combination with fMRI.[54,107,108,111,134,137,138] One showed that impaired ability to postpone rewards was associated with "problematic patterns" of play in multiplayer online games.[54] Another study found that individuals with IGD have poorer impulse control than nonaddicted recreational gamers, mirroring findings distinguishing dependent from recreational cocaine users.[54,139] Brains of individuals with IGD show less frontal cortical-striatal activation during testing, another indication of poor impulse control.[111] The brains of those with severe IGD showed weaker activity in the dorsolateral prefrontal cortex when experiencing risk, and greater activation in the ventral striatum (part of the go network), ventromedial prefrontal cortex, and orbitofrontal cortex when experiencing reward, also indicative of a failure in self-regulation.[140] Overall, research demonstrates that brain abnormalities associated with impulsivity are associated with a higher risk for IGD.

Long-Term Brain Effects

Imaging studies have also demonstrated how severity and duration of IGD cause changes in brain morphology similar to those caused by SUDs. Addiction duration, gaming duration, cognitive deficits, and severity of IGD correlate with disrupted gray and white matter integrity in the dorsolateral prefrontal cortex, orbitofrontal cortex, and striatum.[116,121,135] This may indicate that neuropathology along the mesocorticolimbic pathways is not only a cause of IGD pathology but also a downstream effect as well. These findings strongly support the theory that IVGA causes long-term changes in the brain, similar to those of substance abuse, but it is difficult to draw

firm conclusions without a suitable animal model for IVGA. Newborn mice exposed to constant, variable multimedia exposure for 42 days entered a state of "overstimulation" after which they performed more poorly than controls on tasks measuring anxiety, hyperactivity, memory, and learning.[141] It is tempting to compare this overstimulated state to overuse of screen entertainment, but confounding variables contribute to problems in applying these results to humans. Nonetheless, studies like this one promise that the presence, quality, quantity, and reversibility of long-term brain changes from IVGA will be better illuminated by future research.[141,142]

SUMMARY

In spite of the lack of a consensus on diagnosis, and the resulting variations in epidemiologic, comorbidity, and neurobiological research, these studies provide overwhelming evidence of similarities between IVGA and SUD. Taken as a whole, the research presented here strongly suggests that IVGA is a clinically relevant and valid syndrome. Like other addictions, it is better understood when incorporating a neurobiological perspective. Our field must successfully address IVGAs to meet the needs of a society that is increasingly enmeshed in digital technology. Research in this area should continue to accelerate, allowing clinicians to better screen for, diagnose, psychoeducate, and provide multimodal treatment for our patients with IVGA. Treatment of IVGAs is explored in David N. Greenfield's article, "Treatment Considerations in Internet and Video Game Addiction: A Qualitative Discussion," in this issue.

Significant limitations in the current body of research include the difficulty in determining causality among many epidemiologic correlations, the limited knowledge of brain changes occurring in IVGA, including whether they are reversible, and the absence of animal model studies. These weaknesses will likely continue to encourage challenges to the validity of IVGA from critics. Some argue that digital technology use is so pervasive that the diagnosis may overpathologize behavior that is normative and acceptable in our culture.[105] On the other hand, modern society's excessive engagement with technology risks falsely normalizing addictions to technology, in what may be a culture of "functional tech-oholics." It seems difficult to walk down a public street without seeing multiple passersby engaged with smartphones, or to partake in a group conversation with no mention of digital media in some form. It seems evident that the human brain cannot evolve fast enough to adapt to the progress of digital technology, and that even the most powerful prefrontal cortex may be unable to resist the allure of instant stimulation in the ocean of digital screens that our world is becoming. Regardless of where we place the diagnostic cutoff for IVGA, our patients suffering the most profound dysfunction from their use of digital technology need better resources to recognize, understand, and treat their condition. If IVGA proves to be more abundant than a collection of a few extreme cases, it will be even more vital for our psychoeducational interventions to reach not only affected individuals, but their families and the communities as well. Ironically, social media and other forms of screen-based education may prove the best platforms for reaching out to those suffering IVGA without the insight, knowledge, and resources to address it.[a] This fact reminds us that learning more about the benefits of digital technology as well as its risks represents a challenge for modern providers and an opportunity for contemporary researchers.

[a] As an example of social media–based psychoeducation, the author has created an animated YouTube video designed to educate parents on how the brain responds to prolonged digital technology exposure. It can be accessed at www.cliffordsussmanmd.com by selecting the link "How Does Internet Use and Gaming Affect the Brain?"

REFERENCES

1. Common Sense Media I. The common sense census: media use by tweens and teens. 2015. Available at: https://www.commonsensemedia.org/research/the-common-sense-census-media-use-by-tweens-and-teens. Accessed January 5, 2017.
2. Young KS. Internet addiction: the emergence of a new clinical disorder. Cyberpsychol Behav 1996;1(3):237–44.
3. Weinstein A, Lejoyeux M. Internet addiction or excessive Internet use. Am J Drug Alcohol Abuse 2010;36(5):277–83.
4. Cash H, Rae CD, Steel AH, et al. Internet addiction: a brief summary of research and practice. Curr Psychiatry Rev 2012;8(4):292–8.
5. Weigle P. Internet and video game addiction: evidence & controversy. Adolesc Psychiatry (Hilversum) 2014;4(2):81–91. Available at: http://www.ingentaconnect.com.ezproxy.lb.polyu.edu.hk/content/ben/aps/2014/00000004/00000002/art00004.
6. Kuss DJ, Lopez-Fernandez O. Internet addiction and problematic Internet use: a systematic review of clinical research. World J Psychiatry 2016;6(1):143.
7. American Psychiatric Association. Diagnostic and statistical manual of mental disorders, fifth edition. Arlington (VA): American Psychiatric Publishing; 2013.
8. Kardefelt-Winther D, Heeren A, Schimmenti A, et al. How can we conceptualize behavioural addiction without pathologizing common behaviours? Addiction 2017;1–7. https://doi.org/10.1111/add.13763.
9. Rehbein F, Psych G, Kleimann M, et al. Prevalence and risk factors of video game dependency in adolescence: results of a German Nationwide survey. Cyberpsychol Behav Soc Netw 2010;13(3):269–77.
10. Achab S, Nicolier M, Mauny F, et al. Massively multiplayer online role-playing games: comparing characteristics of addict vs non-addict online recruited gamers in a French adult population. BMC Psychiatry 2011;11(1):144.
11. Ko CH, Yen JY, Chen CC, et al. Proposed diagnostic criteria of Internet addiction for adolescents. J Nerv Ment Dis 2005;193(11):728–33.
12. Ko CH, Yen JY, Chen SH, et al. Proposed diagnostic criteria and the screening and diagnosing tool of Internet addiction in college students. Compr Psychiatry 2009;50(4):378–84.
13. Kim D, Lee Y, Lee J, et al. Development of Korean smartphone addiction proneness scale for youth. PLoS One 2014;9(5):1–8.
14. Kwon M, Lee JY, Won WY, et al. Development and validation of a smartphone addiction scale (SAS). PLoS One 2013;8(2). https://doi.org/10.1371/journal.pone.0056936.
15. Kor A, Zilcha-Mano S, Fogel YA, et al. Psychometric development of the problematic pornography use scale. Addict Behav 2014;39(5):861–8.
16. Pearcy BTD, Roberts LD, McEvoy PM. Psychometric testing of the personal Internet gaming disorder evaluation-9: a new measure designed to assess Internet gaming disorder. Cyberpsychol Behav Soc Netw 2016;19(5):335–41.
17. Griffiths M. A "components" model of addiction within a biopsychosocial framework. J Subst Use 2005;10(4):191–7.
18. Orosz G, Bőthe B, Tóth-Király I. The development of the problematic series watching scale (PSWS). J Behav Addict 2016;5(1):144–50.
19. Orosz G, Tóth-Király I, Bőthe B, et al. Too many swipes for today: the development of the problematic tinder use scale (PTUS). J Behav Addict 2016;5(3):518–23.

20. Andreassen CS, Torsheim T, Brunborg GS, et al. Development of a Facebook addiction scale. Psychol Rep 2012;110(2):501–17.
21. Choi JS, Park SM, Roh MS, et al. Dysfunctional inhibitory control and impulsivity in Internet addiction. Psychiatry Res 2014;215(2):424–8.
22. Park J-S. Development of Internet addiction measurement scales and Korean Internet addiction index. J Prev Med Public Health 2005;38(3):298–306 [in Korean].
23. Romano M, Osborne LA, Truzoli R, et al. Differential psychological impact of Internet exposure on Internet addicts. PLoS One 2013;8(2):8–11.
24. King DL, Delfabbro PH, Zwaans T, et al. Clinical features and axis I comorbidity of Australian adolescent pathological Internet and video game users. Aust N Z J Psychiatry 2013;47(11):1058–67.
25. Rho MJ, Jeong J-E, Chun J-W, et al. Predictors and patterns of problematic Internet game use using a decision tree model. J Behav Addict 2016;5(3):500–9.
26. Moreno MA, Arseniev-Koehler A, Selkie E. Development and testing of a 3-item screening tool for problematic Internet use. J Pediatr 2016;176:167–72.e1.
27. Rafla M, Carson NJ, DeJong SM. Adolescents and the Internet: what mental health clinicians need to know. Curr Psychiatry Rep 2014;16(9). https://doi.org/10.1007/s11920-014-0472-x.
28. Chen YL, Chen SH, Gau SSF. ADHD and autistic traits, family function, parenting style, and social adjustment for Internet addiction among children and adolescents in Taiwan: a longitudinal study. Res Dev Disabil 2015;39:20–31.
29. Lam LT. Internet gaming addiction, problematic use of the Internet, and sleep problems: a systematic review. Curr Psychiatry Rep 2014;16(4):444.
30. Mihara S, Higuchi S. Cross-sectional and longitudinal epidemiological studies of Internet gaming disorder: a systematic review of the literature. Psychiatry Clin Neurosci 2017. https://doi.org/10.1111/pcn.12532.
31. Griffiths M, Pontes H, Kuss D. Clinical psychology of Internet addiction: a review of its conceptualization, prevalence, neuronal processes, and implications for treatment. Neurosci Neuroecon 2015;11. https://doi.org/10.2147/NAN.S60982.
32. Kilic M, Avci D, Uzuncakmak T. Internet addiction in high school students in Turkey and multivariate analyses of the underlying factors. J Addict Nurs 2016;27(1):39–46.
33. Király O, Griffiths MD, Urbán R, et al. Problematic Internet use and problematic online gaming are not the same: findings from a large nationally representative adolescent sample. Cyberpsychol Behav Soc Netw 2014. https://doi.org/10.1089/cyber.2014.0475.
34. Kawabe K, Horiuchi F, Ochi M, et al. Internet addiction: prevalence and relation with mental states in adolescents. Psychiatry Clin Neurosci 2016;70(9):405–12.
35. Shek DTL, Yu L. Adolescent Internet addiction in Hong Kong: prevalence, change, and correlates. J Pediatr Adolesc Gynecol 2016;29(1):S22–30.
36. Wartberg L, Kriston L, Kammerl R, et al. Prevalence of pathological Internet use in a representative German sample of adolescents: results of a latent profile analysis. Psychopathology 2015;48(1):25–30.
37. Bonnaire C, Phan O. Relationships between parental attitudes, family functioning and Internet gaming disorder in adolescents attending school. Psychiatry Res 2017;255:104–10.
38. Ač-Nikolić E, Zarić D, Nićiforović-Šurković O. Prevalence of Internet addiction among schoolchildren in Novi Sad. Srp Arh Celok Lek 2015;143(11–12):719–25.

39. García-Oliva C, Piqueras JA. Experiential avoidance and technological addictions in adolescents. J Behav Addict 2016;5(2):293–303.
40. Ha JH, Kim SY, Bae SC, et al. Depression and Internet addiction in adolescents. Psychopathology 2007;40(6):424–30.
41. Festl R, Scharkow M, Quandt T. Problematic computer game use among adolescents, younger and older adults. Addiction 2013;108(3):592–9.
42. Eichenberg C, Schott M, Decker O, et al. Attachment style and Internet addiction: an online survey. J Med Internet Res 2017;19(5):e170.
43. Ferguson CJ, Coulson M, Barnett J. A meta-analysis of pathological gaming prevalence and comorbidity with mental health, academic and social problems. J Psychiatr Res 2011;45(12):1573–8.
44. Przybylski AK, Weinstein N, Murayama K. Internet gaming disorder: investigating the clinical relevance of a new phenomenon. Am J Psychiatry 2017; 174(3):230–5.
45. Strittmatter E, Parzer P, Brunner R, et al. A 2-year longitudinal study of prospective predictors of pathological Internet use in adolescents. Eur Child Adolesc Psychiatry 2016;25(7):725–34.
46. Lau JTF, Wu AMS, Gross DL, et al. Is Internet addiction transitory or persistent? Incidence and prospective predictors of remission of Internet addiction among Chinese secondary school students. Addict Behav 2017;74:55–62.
47. Gentile DA, Choo H, Liau A, et al. Pathological video game use among youths: a two-year longitudinal study. Pediatrics 2011;127(2):e319–29.
48. Bessière K, Seay AF, Kiesler S. The ideal elf: identity exploration in World of Warcraft. Cyberpsychol Behav 2007;10(4):530–5.
49. Rodgers RF, Melioli T, Laconi S, et al. Internet addiction symptoms, disordered eating, and body image avoidance. Cyberpsychol Behav Soc Netw 2013;16(1): 56–60.
50. Dieter J, Hill H, Sell M, et al. Avatar's neurobiological traces in the self-concept of massively multiplayer online role-playing game (MMORPG) addicts. Behav Neurosci 2015;129(1):8–17.
51. Leménager T, Gwodz A, Richter A, et al. Self-concept deficits in massively multiplayer online role-playing games addiction. Eur Addict Res 2013;19(5):227–34.
52. Subramaniam M, Chua BY, Abdin E, et al. Prevalence and correlates of Internet gaming problem among Internet users: results from an Internet survey. Ann Acad Med Singapore 2016;45(5):174–83.
53. Lemmens JS, Hendriks SJF. Addictive online games: examining the relationship between game genres and Internet gaming disorder. Cyberpsychol Behav Soc Netw 2016;19(4):270–6.
54. Nuyens F, Deleuze J, Maurage P, et al. Impulsivity in multiplayer online battle arena gamers: preliminary results on experimental and self-report measures. J Behav Addict 2016;5(2):351–6.
55. Eichenbaum A, Kattner F, Bradford D, et al. Role-playing and real-time strategy games associated with greater probability of Internet gaming disorder. Cyberpsychol Behav Soc Netw 2015;18(8):480–5.
56. Hilgard J, Engelhardt CR, Bartholow BD. Individual differences in motives, preferences, and pathology in video games: the gaming attitudes, motives, and experiences scales (GAMES). Front Psychol 2013;4:1–13. https://doi.org/10.3389/fpsyg.2013.00608.
57. Lukavska K. Time perspective as a predictor of massive multiplayer online role-playing game playing. Cyberpsychol Behav Soc Netw 2012;15(1):50–4.

58. Lukavská K, Hrabec O, Chrz V. The role of habits in massive multiplayer online role-playing game usage: predicting excessive and problematic gaming through players' sensitivity to situational cues. Cyberpsychol Behav Soc Netw 2016;19(4):277–82.
59. Weinstein A, Dorani D, Elhadif R, et al. Internet addiction is associated with social anxiety in young adults. Ann Clin Psychiatry 2015;27(1):4–9.
60. Caplan SE. Relations among loneliness, social anxiety, and problematic Internet use. Cyberpsychol Behav 2007;10(2):234–42.
61. Zadra S, Bischof G, Besser B, et al. The association between Internet addiction and personality disorders in a general population-based sample. J Behav Addict 2016;5(4):691–9.
62. Oberst U, Wegmann E, Stodt B, et al. Negative consequences from heavy social networking in adolescents: the mediating role of fear of missing out. J Adolesc 2017;55:51–60.
63. Kuss DJ, Griffiths MD. Social networking sites and addiction: ten lessons learned. Int J Environ Res Public Health 2017;14(3). https://doi.org/10.3390/ijerph14030311.
64. Meshi D, Morawetz C, Heekeren HR. Nucleus accumbens response to gains in reputation for the self relative to gains for others predicts social media use. Front Hum Neurosci 2013;7:1–11.
65. Jiang D, Zhu S, Ye M, et al. Cross-sectional survey of prevalence and personality characteristics of college students with Internet addiction in Wenzhou, China. Shanghai Arch Psychiatry 2012;24(2):99–107.
66. Jia R, Jia HH. Maybe you should blame your parents: parental attachment, gender, and problematic Internet use. J Behav Addict 2016;5(3):524–8.
67. Schimmenti A, Passanisi A, Gervasi AM, et al. Insecure attachment attitudes in the onset of problematic Internet use among late adolescents. Child Psychiatry Hum Dev 2014;45(5):588–95.
68. Beutel ME, Hoch C, Wölfling K, et al. Clinical characteristics of computer game and Internet addiction in persons seeking treatment. Z Psychosom Med Psychother 2011;57(1):77–90.
69. Kalaitzaki AE, Birtchnell J. The impact of early parenting bonding on young adults' Internet addiction, through the mediation effects of negative relating to others and sadness. Addict Behav 2014;39(3):733–6.
70. Wu X-S, Zhang Z-H, Zhao F, et al. Prevalence of Internet addiction and its association with social support and other related factors among adolescents in China. J Adolesc 2016;52:103–11.
71. Lam LT. Parental mental health and Internet addiction in adolescents. Addict Behav 2015;42:20–3.
72. Ding Q, Li D, Zhou Y, et al. Perceived parental monitoring and adolescent Internet addiction: a moderated mediation model. Addict Behav 2017;74:48–54.
73. Jelenchick LA, Hawk ST, Moreno MA. Problematic Internet use and social networking site use among Dutch adolescents. Int J Adolesc Med Health 2016;28(1):119–21.
74. Ge Y, Se J, Zhang J. Research on relationship among Internet-addiction, personality traits and mental health of urban left-behind children. Glob J Health Sci 2014;7(4). https://doi.org/10.5539/gjhs.v7n4p60.
75. Choi S-W, Kim D-J, Choi J-S, et al. Comparison of risk and protective factors associated with smartphone addiction and Internet addiction. J Behav Addict 2015;4(4):308–14.

76. Yu H, Cho J. Prevalence of Internet gaming disorder among Korean adolescents and associations with non-psychotic psychological symptoms, and physical aggression. Am J Health Behav 2016;40(6):705–16.
77. Wartberg L, Brunner R, Kriston L, et al. Psychopathological factors associated with problematic alcohol and problematic Internet use in a sample of adolescents in Germany. Psychiatry Res 2016;240:272–7.
78. Andreassen CS, Billieux J, Griffiths MD, et al. The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: a large-scale cross-sectional study. Psychol Addict Behav 2016;30(2):252–62.
79. Tang CSK, Koh YYW. Online social networking addiction among college students in Singapore: comorbidity with behavioral addiction and affective disorder. Asian J Psychiatr 2017;25:175–8.
80. Liu C-H, Lin S-H, Pan Y-C, et al. Smartphone gaming and frequent use pattern associated with smartphone addiction. Medicine (Baltimore) 2016;95(28):e4068.
81. Weinstein A, Yaacov Y, Manning M, et al. Internet addiction and attention deficit hyperactivity disorder among schoolchildren. Isr Med Assoc J 2015;17(12):731–4.
82. Durkee T, Carli V, Floderus B, et al. Pathological Internet use and risk-behaviors among European adolescents. Int J Environ Res Public Health 2016;13(3). https://doi.org/10.3390/ijerph13030294.
83. Tan Y, Chen Y, Lu Y, et al. Exploring associations between problematic Internet use, depressive symptoms and sleep disturbance among southern Chinese adolescents. Int J Environ Res Public Health 2016;13(3):1–12.
84. Lim J-A, Gwak AR, Park SM, et al. Are adolescents with Internet addiction prone to aggressive behavior? The mediating effect of clinical comorbidities on the predictability of aggression in adolescents with Internet addiction. Cyberpsychol Behav Soc Netw 2015;18(5):260–7.
85. Melchers M, Li M, Chen Y, et al. Low empathy is associated with problematic use of the Internet: empirical evidence from China and Germany. Asian J Psychiatr 2015;17:56–60.
86. Tsimtsiou Z, Haidich A-B, Drontsos A, et al. Pathological Internet use, cyberbullying and mobile phone use in adolescence: a school-based study in Greece. Int J Adolesc Med Health 2017;2013–5. https://doi.org/10.1515/ijamh-2016-0115.
87. Gámez-Guadix M, Borrajo E, Almendros C. Risky online behaviors among adolescents: longitudinal relations among problematic Internet use, cyberbullying perpetration, and meeting strangers online. J Behav Addict 2016;5(1):100–7.
88. Braun B, Kornhuber J, Lenz B. Gaming and religion: the impact of spirituality and denomination. J Relig Health 2016;55(4):1464–71.
89. Lee S-Y, Lee HK, Jeong H, et al. The hierarchical implications of Internet gaming disorder criteria: which indicate more severe pathology? Psychiatry Investig 2017;14(3):249.
90. Kim DJ, Kim K, Lee H-W, et al. Internet game addiction, depression, and escape from negative emotions in adulthood: a nationwide community sample of Korea. J Nerv Ment Dis 2017. https://doi.org/10.1097/NMD.0000000000000698.
91. Reed P, Romano M, Re F, et al. Differential physiological changes following Internet exposure in higher and lower problematic Internet users. PLoS One 2017;12(5):1–11.

92. Shensa A, Escobar-Viera CG, Sidani JE, et al. Problematic social media use and depressive symptoms among U.S. young adults: a nationally-representative study. Soc Sci Med 2017;182:150–7.
93. Park S, Jeon HJ, Son JW, et al. Correlates, comorbidities, and suicidal tendencies of problematic game use in a national wide sample of Korean adults. Int J Ment Health Syst 2017;11(1):35.
94. Morrison CM, Gore H. The relationship between excessive Internet use and depression: a questionnaire-based study of 1,319 young people and adults. Psychopathology 2010;43(2):121–6.
95. Lehenbauer-Baum M, Klaps A, Kovacovsky Z, et al. Addiction and engagement: an explorative study toward classification criteria for Internet gaming disorder. Cyberpsychol Behav Soc Netw 2015;18(6):343–9.
96. Floros G, Siomos K, Stogiannidou A, et al. Comorbidity of psychiatric disorders with Internet addiction in a clinical sample: the effect of personality, defense style and psychopathology. Addict Behav 2014;39(12):1839–45.
97. Alpaslan AH, Soylu N, Kocak U, et al. Problematic Internet use was more common in Turkish adolescents with major depressive disorders than controls. Acta Paediatr 2016;105(6):695–700.
98. Ho RC, Zhang MW, Tsang TY, et al. The association between Internet addiction and psychiatric co-morbidity: a meta-analysis. BMC Psychiatry 2014;14(1):183.
99. Tateno M, Teo AR, Shirasaka T, et al. Internet addiction and self-evaluated attention-deficit hyperactivity disorder traits among Japanese college students. Psychiatry Clin Neurosci 2016;70(12):567–72.
100. Hu J, Zhen S, Yu C, et al. Sensation seeking and online gaming addiction in adolescents: a moderated mediation model of positive affective associations and impulsivity. Front Psychol 2017;8:1–8.
101. So R, Makino K, Fujiwara M, et al. The prevalence of Internet addiction among a Japanese adolescent psychiatric clinic sample with autism spectrum disorder and/or attention-deficit hyperactivity disorder: a cross-sectional study. J Autism Dev Disord 2017;47(7):2217–24.
102. Wölfling K, Beutel ME, Dreier M, et al. Bipolar spectrum disorders in a clinical sample of patients with Internet addiction: hidden comorbidity or differential diagnosis? J Behav Addict 2015;4(2):101–5.
103. Chuang C-WI, Sussman S, Stone MD, et al. Impulsivity and history of behavioral addictions are associated with drug use in adolescents. Addict Behav 2017;74:41–7.
104. Baysan-Arslan S, Cebci S, Kaya M, et al. Relationship between Internet addiction and alexithymia among university students. Clin Invest Med 2016;39(6):S111–5.
105. Zastrow M. News feature: is video game addiction really an addiction? Proc Natl Acad Sci U S A 2017;114(17):4268–72.
106. Adinoff B. Neurobiologic processes in drug reward and addiction. Harv Rev Psychiatry 2004;12(6):305–20.
107. Jorgenson AG, Hsiao RCJ, Yen CF. Internet addiction and other behavioral addictions. Child Adolesc Psychiatr Clin N Am 2016;25(3):509–20.
108. Wang Y, Wu L, Wang L, et al. Impaired decision-making and impulse control in Internet gaming addicts: evidence from the comparison with recreational Internet game users. Addict Biol 2016. https://doi.org/10.1111/adb.12458.
109. Moschak TM, Carelli RM. Impulsive rats exhibit blunted dopamine release dynamics during a delay discounting task independent of cocaine history. ENeuro 2017;4:1–12.

110. Adisetiyo V, Gray KM. Neuroimaging the neural correlates of increased risk for substance use disorders in attention-deficit/hyperactivity disorder—a systematic review. Am J Addict 2017;26(2):99–111.
111. Dong G, Li H, Wang L, et al. Cognitive control and reward/loss processing in Internet gaming disorder: results from a comparison with recreational Internet game-users. Eur Psychiatry 2017;44:30–8.
112. Dobbs LK, Lemos JC, Alvarez VA. Restructuring of basal ganglia circuitry and associated behaviors triggered by low striatal D2 receptor expression: implications for substance use disorders. Genes Brain Behav 2017;16(1):56–70.
113. Blum K, Chen A, Chen TJ, et al. Activation instead of blocking mesolimbic dopaminergic reward circuitry is a preferred modality in the long term treatment of reward deficiency syndrome (RDS): a commentary. Theor Biol Med Model 2008;5(1):24.
114. Dalley JW, Everitt BJ, Robbins TW. Impulsivity, compulsivity, and top-down cognitive control. Neuron 2011;69(4):680–94.
115. Noël X, Van der Linden M, Bechara A. The neurocognitive mechanisms and loss of willpower. Psychiatry (Edgmont) 2006;3(5):30–41.
116. Weinstein A, Lejoyeux M. New developments on the neurobiological and pharmaco-genetic mechanisms underlying Internet and videogame addiction. Am J Addict 2015;24(2):117–25.
117. Koepp MJ, Gunn RN, Lawrence AD, et al. Evidence for striatal dopamine release during a video game. Nature 1998;393(6682):266–8.
118. Wanat MJ, Kuhnen CM, Phillips PEM. Delays conferred by escalating costs modulate dopamine release to rewards but not their predictors. J Neurosci 2010;30(36):12020–7.
119. Peraile I, Torres E, Mayado A, et al. Dopamine transporter down-regulation following repeated cocaine: implications for 3,4-methylenedioxymethamphetamine-induced acute effects and long-term neurotoxicity in mice. Br J Pharmacol 2010;159(1):201–11.
120. Kuss DJ. Internet gaming addiction: current perspectives. Psychol Res Behav Manag 2013;6:125–37.
121. Choi J, Cho H, Kim J-Y, et al. Structural alterations in the prefrontal cortex mediate the relationship between Internet gaming disorder and depressed mood. Sci Rep 2017;7(1):1245.
122. Kim SH, Baik S-H, Park CS, et al. Reduced striatal dopamine D2 receptors in people with Internet addiction. Neuroreport 2011;22(8):407–11.
123. Hou H, Jia S, Hu S, et al. Reduced striatal dopamine transporters in people with Internet addiction disorder. J Biomed Biotechnol 2012;2012. https://doi.org/10.1155/2012/854524.
124. Hahn T, Notebaert KH, Dresler T, et al. Linking online gaming and addictive behavior: converging evidence for a general reward deficiency in frequent online gamers. Front Behav Neurosci 2014;8:1–6.
125. Han DH, Lee YS, Yang KC, et al. Dopamine genes and reward dependence in adolescents with excessive Internet video game play. J Addict Med 2007;1(3):133–8.
126. Volkow ND, Chang L, Wang GJ, et al. Low level of brain dopamine D2 receptors in methamphetamine abusers: association with metabolism in the orbitofrontal cortex. Am J Psychiatry 2001;158(12):2015–21.
127. Volkow ND, Wang GJ, Smith L, et al. Recovery of dopamine transporters with methamphetamine detoxification is not linked to changes in dopamine release. Neuroimage 2015;121:20–8.

128. Pennay AE, Lee NK. Putting the call out for more research: the poor evidence base for treating methamphetamine withdrawal. Drug Alcohol Rev 2011;30(2):216–22.
129. Gola M, Wordecha M, Sescousse G, et al. Can pornography be addictive? An fMRI study of men seeking treatment for problematic pornography use. Neuropsychopharmacology 2017;5:1–11.
130. Ko CH, Liu GC, Hsiao S, et al. Brain activities associated with gaming urge of online gaming addiction. J Psychiatr Res 2009;43(7):739–47.
131. Ko CH, Liu GC, Yen JY, et al. Brain correlates of craving for online gaming under cue exposure in subjects with Internet gaming addiction and in remitted subjects. Addict Biol 2013;18(3):559–69.
132. Bae S, Han DH, Kim SM, et al. Neurochemical correlates of Internet game play in adolescents with attention deficit hyperactivity disorder: a proton magnetic resonance spectroscopy (MRS) study. Psychiatry Res 2016;254:10–7.
133. Kühn S, Gallinat J. Brains online: structural and functional correlates of habitual Internet use. Addict Biol 2015;20(2):415–22.
134. Meng Y, Deng W, Wang H, et al. The prefrontal dysfunction in individuals with Internet gaming disorder: a meta-analysis of functional magnetic resonance imaging studies. Addict Biol 2015;20(4):799–808.
135. Weng C-B, Qian R-B, Fu X-M, et al. Gray matter and white matter abnormalities in online game addiction. Eur J Radiol 2013;82(8):1308–12.
136. Kim J-Y, Jeong J-E, Rhee J-K, et al. Targeted exome sequencing for the identification of a protective variant against Internet gaming disorder at rs2229910 of neurotrophic tyrosine kinase receptor, type 3 (NTRK3): a pilot study. J Behav Addict 2016;5(4):631–8.
137. Buono FD, Sprong ME, Lloyd DP, et al. Delay discounting of video game players: comparison of time duration among gamers. Cyberpsychol Behav Soc Netw 2017;20(2):104–8.
138. Van Holst RJ, Lemmens JS, Valkenburg PM, et al. Attentional bias and disinhibition toward gaming cues are related to problem gaming in male adolescents. J Adolesc Health 2017;50(6):541–6.
139. Fernandez-Serrano MJ, Cesar Peraleslopez J, Moreno-Lopez L, et al. Impulsivity and compulsivity in cocaine dependent individuals. Adicciones 2012;24(2):105–13 [in Spanish].
140. Liu L, Xue G, Potenza MN, et al. Dissociable neural processes during risky decision-making in individuals with Internet-gaming disorder. Neuroimage Clin 2017;14:741–9.
141. Christakis DA, Ramirez JSB, Ramirez JM. Overstimulation of newborn mice leads to behavioral differences and deficits in cognitive performance. Scientific Reports 2012;2(546). https://doi.org/10.1038/srep00546.
142. Ravinder S, Donckels EA, Ramirez JSB, et al. Excessive sensory stimulation during development alters neural plasticity and vulnerability to cocaine in mice. eNeuro 2016;3:1–11.