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Are Internet use and video-game-playing addictive behaviors? Biological, clinical and public health implications for youths and adults

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Abstract

Internet use and video-game playing are experiencing rapid growth among both youth and adult populations. Research suggests that a minority of users experience symptoms traditionally associated with substance-related addictions. Mental health professionals, policy makers and the general public continue to debate the issue of Internet addiction (IA) and problematic video-game playing (PVG). This review identifies existing studies into the clinical and biological characteristics of these disorders that may help guide decisions as to whether or not IA and PVG should be grouped together with substance use disorders (SUDs).

Keywords

Internet addiction; Video-games; Substance use disorder; Classification; Prevalence; Neurobiology; Growth and development

Introduction

The past two decades have witnessed a revolution in the use of digital technologies; the implementation of advanced hardware and software is greatly shaping modern society. In particular, the Internet and video-game industries are experiencing rapid growth, with expanding rates of use that arguably have only been matched by the advent of television. It is, therefore, not surprising that different individuals (e.g., based on differences in gender, age and other factors including some linked to motivation, attention and interest) may demonstrate non-uniform participation in these media.

The average 13-24 year-old person in the United States spends 16.7 hours per week using the Internet for activities other than email; this compares with the 13.6 hours per week spent watching television (1). Although there is still no consensus as to what constitutes ‘Internet

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addiction' (IA), it has been proposed that IA is characterized by excessive or poorly controlled urges and a maladaptive obsession with the Internet (2). Approximately 86% of IA cases have another DSM-IV-TR diagnosis present (3), leading some to argue that the Internet in itself is not an issue; rather, the content (e.g. gambling, pornography, or gaming – for example, in massive multiplayer online games (MMOG)) to which it facilitates access is the concern (4). Whether comorbidities with such conditions as pathological gambling, hypersexual disorder or problematic video-gaming (PVG) may define IA and be reflected in shared etiological factors or may reflect IA being a "secondary disorder" remains an important and debated consideration. Because of its diverse nature, IA has been proposed to separate into three subtypes (5): excessive gaming, sexual preoccupation and email/text messaging. This segregation may itself have limitations as the use of the Internet for social networking has increased significantly in recent years and thus may represent a fourth subtype in this model.

Concurrent with Internet growth, the video-game industry has expanded, with video-games captivating the attention of many youths. Video-game-playing arguably began with the development of 'Pong' in 1972. By 1974, computerized Pong machines were "in every bar and bowling alley across the United States" (6). Video-games are now no longer limited to big, unaffordable machines and are becoming increasingly accessible with 83% of youths reporting having at least one gaming console in their homes (7).

Availability, coupled with the substantial increase in the amount of time youths spend on the Internet (1) and playing video-games, (8) has raised concerns amongst researchers regarding the potential for some youths (as well as older individuals) to demonstrate pathological or addictive patterns of Internet use (9-13) and gaming (4, 14-16). The present article will first consider IA and PVG (also referred to as "video-game addiction") as technology-related behaviors that may be conceptualized within an addiction framework, and will then explore the clinical and public health implications.

Despite some possible positive benefits of video-game-playing in educational (17) and visual-skills (18, 19) domains, video-game playing may go from being recreational to addictive when performed excessively (20). While negative consequences of PVG arguably may not be as recognizable or detrimental as those of substance use disorders (SUDs), excessive or compulsive use of video-games may interfere with important aspects of daily life as motivated behaviors disproportionately involve video-game-playing as compared with school work or interactions with family members or peers. According to the "displacement theory" (21), time spent on gaming can displace time that may be essential for other activities such as school work (22). Choosing to engage in video-gaming instead of school–related or other important behaviors may have both short-term and long-term consequences, particularly as behaviors may become more habitual or compulsive over time (23, 24). As such, although engagement in certain types of video-games may be more risky or problematic than others, excessive or interfering video-game-playing in any form may be potentially problematic (25, 26). Excessive video gaming has been linked in preliminary studies or reports with multiple health conditions including auditory hallucinations (27), repetitive strain injuries (28), 'nintendinitis' (a type of repetitive strain injury relating to the overuse of a gamepad or joystick) (29, 30), enuresis (31), encopresis (32) and epileptic seizures (33). In severe cases, excessive video-game-playing has been cited as a possible contributing factor in deaths in Korea (34) and the United States (35).

Considering IA and PVG in the Diagnostic and Statistical Manual (DSM)

Currently there are no formal diagnostic criteria for a disorder characterized by excessive or interfering patterns of video-game-playing or Internet use. There presently exists a category

in the current edition of the DSM (36) entitled, “Impulse Control Disorders Not Elsewhere Classified.” These conditions share a common feature of a “failure to resist an impulse, drive or temptation to perform an act that is harmful to the person or to others ... the individual feels an increasing sense of tension or arousal before committing the act and then experiences pleasure, gratification, or relief at the time of committing the act” (36). This category currently includes formal diagnostic criteria for pathological gambling, pyromania, kleptomania, intermittent explosive disorder (characterized by an interfering pattern of performance of impulsively aggressive acts), and trichotillomania (characterized by repetitive and interfering patterns of hair-pulling). Within this category, there also exists a diagnosis entitled, “Impulse Control Disorder Not Otherwise Specified” that could be used for individuals with excessive or interfering patterns of behavior in other domains including shopping, sex, skin-picking or nail-biting, Internet use, or video-game-playing (36, 37).

How best to categorize impulse control disorders has been debated. It has been proposed that these disorders lie along an impulsive-compulsive spectrum and might best be characterized as obsessive-compulsive-spectrum disorders (38). Others have suggested that impulse control disorders might represent behavioral or non-substance addictions (39, 40). These conceptualizations are not mutually exclusive and have important implications for the development of effective prevention and treatment strategies for the disorders. Existing data suggest that some impulse control disorders (e.g., grooming-related conditions like trichotillomania) may be more closely linked to obsessive-compulsive disorder (41, 42), although it has been suggested that trichotillomania is heterogenous with some individuals demonstrating more obsessive-compulsive-disorder-like features and others more addiction-like features (43). Others impulse control disorders (e.g., pathological gambling) may in general be more closely linked to SUDs (44-46). Based on such data, it has been proposed that pathological gambling be moved into a category with SUDs in DSM-5 (47). Which impulse control disorders might best be classified with obsessive-compulsive disorder and which with SUDs is currently being considered for possible changes in DSM-5.

Several researchers have paralleled PVG and IA with pathological gambling as all three may begin as entertainment that stimulates both positive psychological and physical responses (16, 48-50) and later may become dysfunctional. Consistent with this notion, definitions of PVG (15, 16, 51, 52) and IA (12, 53, 54) have often been based on DSM criteria for pathological gambling.

Although some (e.g., (26)) might argue that PVG is part of IA and both should be grouped together under pathological technology use (PTU), it is useful to consider each disorder individually, particularly as gaming often occurs independently of the Internet (on non-Internet-connected consoles) and may be associated with different clinical and health-related characteristics. Video-game-playing is both similar to and distinct from gambling and Internet use in availability and use of visual and auditory rewards, and the differences may contribute to PVG's unique features (55, 56).

How PVG and IA might be best categorized warrants direct investigation. A first step in this process might involve the generation of standardized diagnostic criteria for PVG and IA, as well as investigations into the prevalence, clinical characteristics and biological and environmental contributions to the conditions.

Given the above-cited limitations with respect to not having a uniformly agreed-upon definition for PVG and IA, we have reviewed the literature to identify studies that might provide insight into the prevalence, clinical characteristics and biological underpinnings of PVG and IA. Based on the existing data, we next discuss prevention and treatment implications. Throughout this process, we consider relationships with SUDs and

pathological gambling and whether efforts in understanding and addressing PVG and IA might be informed by work performed in the substance-addiction and pathological-gambling realms.

Clinical and phenomenological characteristics: relationship to substance dependence

In order to consider PVG and IA as behavioral addictions, it is first important to define the term 'addiction'. While addiction was not initially related to substance use behaviors, the term has been associated with impaired control over substance use behaviors for the past several hundred years (57). Recent shifts, however, appear to be returning towards the original meaning of the Latin word, *addicere,* which translates to "enslaved to" or "bound by", and thus may be applicable to both non-substance-related and substance-related disorders alike (58, 59).

Much like its substance-related counterparts, behavioral addictions are characterized by failures to resist impulses, drives or cravings, compulsive performance of the behavior, and diminished control over engagement in the behavior despite the knowledge of associated adverse consequences (45, 57, 60). Furthermore, over time, individuals may experience less pleasure from the behavior (61) and require a higher intensity and/or frequency to achieve the same effects (61-63), akin to tolerance (5, 64).

Video-game-playing and Internet use, like other behaviors underlying impulse control disorders, may be considered as lying along a continuous spectrum. As such, there is not a uniform consensus about what level of behavioral engagement constitutes a problem or an addiction. Although there has been no widely agreed-upon threshold for defining video-game-playing or Internet use as an addiction, excessive engagement involving interference in major activities of daily life has been associated with clinical and biological correlates similar to those of SUDs (65-67). Like with SUDs, such interference at different ages could have developmental implications impacting individuals later in life.

Both similarities and differences between behavioral addictions and SUDs extend beyond the inclusionary criteria; for example, pathological gambling and SUDs share other clinical characteristics such as impulsivity, risk/reward decision-making and neurobiological underpinnings (for review: (44)). Of the behavioral addictions, pathological gambling has received the most research attention and has the most empirical support for relationships with SUDs, although preliminary evidence also suggests a relationship between SUDs and both IA and PVG.

A recent review of 17 prevalence studies suggests that adolescents expressing IA or substance use behaviors display common characteristics including high novelty-seeking behavior and low reward dependence (2). Adolescents with problematic alcohol use were more likely to have IA and show certain psychosocial features including high behavior activation, low self-esteem, low family function and low life satisfaction (68). Adolescent pathological gamblers and high frequency video-game players both score highly on risk-taking measures (69). SUDs have been associated with sensation seeking (70), which has also been positively correlated with PVG (14), particularly for those engaged in compulsive online-gaming (71). Other shared features include impulsivity (72, 73), low social competence (74, 75), low academic performance (76, 77) and, in the case of violent video-games, aggression or violence (22). Though most studies focus on the clinical characteristics of PVG behavior in youth (78), similar findings have been reported for adults (79), indicating that PVG is not solely a youth problem behavior.

Comorbidities

Existing data suggest that IA frequently co-occurs with not only pathological gambling (80) and SUDs (81, 82), but also other psychiatric conditions including attention-deficit hyperactivity, mood, anxiety and personality disorders (83-85). Psychiatric comorbidity in youths with PVG is relatively less established. Data suggest comorbidity with attention problems such as ADHD (86-89); adolescents reporting PVG behaviors were 2.77 times more likely to be diagnosed with ADHD than controls (89). Research also suggests a link with mood disorders (73, 86, 88, 90) and SUDs (particularly those involving tobacco and "hard" drug use) (90).

Data from adult populations have yielded mixed results. In a survey of 1945 healthy participants above 14 years of age (91), individuals with and without PVG did not differ in regard to the frequency of alcohol and illicit drug use, although PVG individuals showed excessive use of caffeinated drinks. Among a sample of 1196 "regular" or "occasional" adult video-game players from the United States, PVG was associated with not only caffeine consumption, but also with tobacco, alcohol, marijuana, and painkiller use problems (92). Differences may reflect the assessments used. While the former study based "PVG" on criteria thought to be associated with behavioral addictions (e.g., craving, loss of control and interference with daily life), not all criteria observed in addictions were included (e.g., withdrawal and tolerance). The latter study implemented the Problem Video-game Playing Scale (16) which assesses PVG based on adaptions of the DSM-IV criteria for SUDs and pathological gambling, covering more addiction-related features.

Prevalence

There is no single standard practice for measuring the prevalence of IA or PVG. There are some more commonly used measures for IA, such as Young's Internet Addiction Scale, and this has demonstrated sufficient reliability (13, 83, 88, 93). Unfortunately, there is less agreement on a formal PVG assessment. One promising assessment tool appears to be the Problem Video-game Playing Scale (16), although it is still not commonly implemented.

As with substance dependence, high prevalence estimates have been reported for IA (Table I) and PVG (Table II) among adolescents and young adults. Prevalence estimates of both have typically ranged from 4-12%. A national Harris Poll survey found that 88% of U.S. youth aged 8-18 years played video-games occasionally, and 8.5% of these gamers were considered problematic players (89). A state-wide study surveying over 4,000 high-school students in Connecticut, U.S.A., reported that 51.2% of the total sample reported video-game-playing, among whom 4.9% fulfilled the criteria for PVG (90). In the same sample, 28.5% of respondents reported spending 15 or more hours per week on the Internet, 4% of the total sample fulfilled the criteria for IA (10). Studies in other countries have found similar results. Among 3,327 Norwegian adolescents (aged 12-18 years) internet users, 4% showed IA with an additional 17.7% showing at-risk use (9) while 4.2% of weekly gamers showed PVG with an additional 15.5% showing at-risk use (15). In the United Kingdom, 20% of adolescents aged 12-17 years met computer dependence based on a scale adapted from the DSM-III-R criteria for pathological gambling (94). In a sample of 517 Taiwanese adolescents aged 12-16 years (95), incidence rate of 7.5% and a remission rate of 49.5% for IA was observed over one year. Among 328 Korean high school seniors, 4.9% showed excessive Internet use (96); a larger study of 903 Korean high school students estimated a 10.7% prevalence (97). Results from a sample of 6,121 Chinese youth aged 11-18 years in Hong Kong reported a particularly high rate (19.1%) of individuals fulfilling the criteria for IA (98).

Reliable data from older age groups are largely lacking and prevalence estimates are arguably more varied. In one of the first large-scale prevalence study of IA, while only 0.7% met IA criteria, it was reported that 3.7% to 13.7% of 2,513 adults across the United States endorsed one or more of the following features: (1) experienced Internet use that interfered with relationships, (2) felt preoccupied with Internet use when offline, (3) tried unsuccessfully to cut down, or (4) stayed online longer than intended (99). In Norway, among 3,399 adults, 1% met criteria for IA and an additional 5.2% were considered at-risk Internet users (100). In the United Kingdom, 18.3% of University students were considered pathological Internet users (101). In a German sample with a wider age range (15-27 year olds, 11.9% of 7069 gamers fulfilled diagnostics criteria for PVG (102).

A recent meta-analysis of 30 journal articles and 3 doctoral dissertations published between the years of 2001 and early 2011 reported three key findings (103). First, studies that based PVG criteria on criteria for pathological gambling reported higher overall prevalence statistics (8.9%) as compared to those that focus on the interfering effects of PVG (3.1%). Second, irrespective of assessment method, online samples reported higher prevalence estimates (9.6%) than off-line samples (4.4%). Third, prevalence estimates were lower in youth samples (4.2%) than in adult samples (8.9%). To our knowledge, there is currently no published meta-analytic study of IA prevalence.

Gender differences

Boys typically report spending more time on the Internet than do girls (10, 100); boys also more frequently acknowledge playing video-games (7, 73, 90, 104, 105). The overall prevalence of IA does not seem to differ between the genders, although boys appear more likely to report missing important school or social activities as a result (10). Boys, however, according to a study based on a PVG assessment tool adapted from DSM-IV criteria for pathological gambling, endorsed more PVG symptoms (73, 89). However, while video-game playing was not associated with negative health measures amongst boys, it was associated with measures of aggression and violence amongst girls (90). These findings suggest that video-game-playing may be a normative behavior amongst boys, at least currently in the U.S. (90).

The exact reasons for observed gender-related differences in video-game-related behaviors are not well understood. Differences in preferred genres of game-playing and personality may contribute to the findings. Boys appear twice as likely as girls to buy M-rated games (89) and preferred physically oriented video-games; in contrast, girl's preferred strategic games (106). However, the association between video-game-playing and violence/aggression in girls suggests the need for additional investigation in this area and into the etiology of the association (e.g., are violent/aggressive girls attracted to video-game-playing or does playing particular games lead to violence and aggression?). Gender-related differences may extend to controlling engagement in video-game-playing as girls made more attempts to cut back video gaming behavior (89).

Gender-related differences in adults are less researched and hence, less clear. Some data suggest that men are more likely than women to report video-game-playing behavior (more than 2 hours a week) (107) while others propose the opposite, where gaming is slightly more prevalent amongst females than males if looking at a wide age group (14-81 years of age) (108). Other studies suggest that approximately equal numbers of men and women in college play video-games (109). The extent to which there are altering patterns of gender-related differences in patterns and types of video-game-playing thus warrants further examination.

Although the majority of prevalence studies yield similar estimates, the lack of a common measure or definition coupled with differences in assessment measures may influence the findings. As such, estimates of prevalence should be considered as informative but preliminary.

Course of Development

While there are emerging data on the excessive and potentially pathological use of the Internet and video-games, most studies are based on cross-sectional designs. These provide insight into the relationships between the disorders and variables but are insufficient to infer causal relationships. Little is known about the course of IA or PVG with some data coming from several recently published longitudinal studies.

The prevalence of video-game playing and Internet use and problematic engagement in each may change over time. A 2-year study of Canadian adolescents from 14 to 16 years of age suggests that there is no change in the prevalence of Internet use and a decrease in the frequency of video-game-playing with age among both genders (110).

As noted above, there has been debate as to whether PVG and IA represent primary disorders that contribute to the development of other disorders or if they represent secondary disorders arising from other disorders. In a 2-year study (111), 2,162 adolescents (between 11-13 years of age) in ten high schools in Taiwan were studied using Chen's Internet Addiction Scale. ADHD and hostility represent potential risk factors for IA in both genders. Depression and social phobia were reported as potential risk factors only among girls. In a 1-year study of 13-16 years old adolescents in the Netherlands, addicted heavy online-gamers generally scored higher on depression, loneliness, social anxiety and negative self-esteem scales throughout the study time-frame, and at the end of the 1-year period addicted “heavy” online gamers of both genders scored higher on the depression scale than did non-addicted “heavy” online gamers (112). In China, adolescents (aged 13-18 years) exhibiting pathological use of the Internet were 2.5 times more likely to develop depressive symptoms 9 months later than those who did not show IA symptoms (based on Young's Internet Addiction Scale) (113). In Singapore, a study of 3034 primary school (average age of 9 years) and secondary school (average age of 13 years) students generated similar findings (73). Depression as well as anxiety and social phobia became worse at the end of a two-year period if the children or adolescent developed PVG during this period. Interestingly, these features may improve when one stops being a problematic gamer. These findings suggest similarities with pathological gambling in which improvement in anxiety and mood domains has accompanied improvement in problem gambling (114).

Although these studies represent a promising start to understanding the course of development of both IA and PVG, there are multiple limitations. Most capture a short time-frame (typically only spanning nine months to two years) that is insufficient in capturing a larger developmental picture, leaving questions about possible effects of age of onset and other developmental factors unanswered. Focus has generally been placed upon adolescents with little to no research conducted on children or adults. Furthermore, there are potential sex differences in in the development of problematic behavior that should be considered, particularly when devising prevention and intervention strategies. At a minimum, these results suggest that there are psychiatric comorbidities but cannot attest to the extent to which IA and PVG may represent predictors or outcomes of other disorders. The extent to which there exist shared risk factors, either genetic or environmental, that may contribute to the onset or persistence of PVG and IA also represents an important knowledge gap.

Personality and neurocognitive features

Knowing what personality traits or characteristics differentiate PVG from non-problematic playing and IA from non-problematic use may assist in identifying which individuals may have PVG or IA as well as those who may be at elevated risk. While there appears to be no one specific IA or PVG persona, common personality and neurocognitive features have been described in IA, PVG and SUDs.

As in individuals with SUDs (e.g., (70, 115-119)), features of increased novelty seeking, low reward dependence (for review: (2)), impulsivity (120), high risk-taking (69), low self-esteem (12, 101) and disadvantageous decision-making (121) have been noted in people with IA. Studies of PVG have reported similar findings relating to sensation seeking (14), self-esteem (122, 123), aggression (71, 124, 125), self-regulation (126) and trait emotional intelligence (127). Out of these features, only self-regulation has been shown to demonstrate value in predicting PVG in a longitudinal setting. In 4490 respondents to a three-wave online survey spanning over 14 months (126), self-regulation deficits predicted the development of PVG.

It is possible that certain genres of video-games may appeal to and/or maintain the problematic behavior of certain groups of individuals more so than others. For example, violent video-games have been linked to aggression. Aggression and diminished empathy have been observed in players whose game of choice contains aggressive contents as compared to players who prefer other genres of games (22, 128, 129). However, the extent to which the genre of video-game attracts particular individuals or the game-playing influences individual tendencies is not well understood.

While there are significant overlaps, unique features between SUDs and PTU have been reported. According to Gray's personality theory (130), there are two dimensions of personality (namely anxiety and impulsivity) which are regulated by the Behavioral Inhibition System (BIS) responsible for aversive motivation and the Behavior Approach System (BAS) which controls appetitive motivation. One study found that while college students with IA scored highly on both the BIS and BAS scale, those with harmful alcohol use scored lower on the BIS scale despite also scoring high on the BAS scale (82). Adolescents with IA also show high harm avoidance, in contrast with low harm avoidance among adolescents with SUDs (131). Unfortunately, research is lacking into the behavioral tendencies associated with PVG.

The relationship between PTU and individual differences related to personality appears complicated. For example, a short-term longitudinal study over 14 months found that impulsivity may pre-date PVG but also worsens after becoming a problematic gamer (73). White these findings are similar to those from the substance addiction field (44), further longitudinal research is needed to more fully understand IA and PVG within a developmental context.

Neural features

Shared brain vulnerabilities have been observed in behavioral addictions and SUDs (39). Currently, there have been very few studies on the neural features of IA or PVG. However, given the high comorbidity plus common clinical, personality and neurocognitive features between PVG and IA with SUDs, one might hypothesize common neurobiologies.

Dopaminergic systems influencing reward and reinforcing behaviors have been implicated in SUDs and behavioral addictions such as pathological gambling (44, 132). For example striatal dopamine appears relevant to drug addictions, particularly stimulant use disorders, as

well as excessive consumption of food (e.g., in obesity – see (39)). In a study using [^{11}C]raclopride during positron emission tomography (PET) scanning (133), adult males with IA had reduced dopamine D2 receptor availability in the bilateral caudate and left putamen compared to controls; the degree of dopamine receptor availability was inversely correlated with the severity of IA. Video-game-playing may also influence the dopaminergic system. In an early neurobiological study of video-game-playing (50) using [^{11}C]raclopride —PET scanning, increased release of dopamine to D2-like receptors, particularly in the ventral striatum, was suggested following a 50-minute video-game play in 8 healthy adult males. A more recent study using single photon emission computed tomography (SPECT) suggests that the level of dopamine release in the ventral striatum during a motorbike riding computer game (134) is comparable to that induced by psychostimulant drugs such as amphetamine (135) and methylphenidate (136). However, it must be noted that neither study assessed PVG individuals and therefore cannot attest to possible changes in the dopaminergic system associated with PVG. Taken together, these findings suggest that IA is associated with dopaminergic neural systems in a fashion similar to substance-related addictions while the relationship between PVG and the dopaminergic systems remain to be explored.

Data collected using functional magnetic resonance imaging (fMRI) has implicated the striatum. Typically, greater ventral striatal activation has been associated with anticipation and feedback of reward (137). Volumetric differences in this area have also been noted in SUDs (138-140). In one of the largest imaging study conducted in the field of PVG to date (49), both structural and functional measures were obtained in 154 14-year-olds. Greater left ventral striatal grey matter volume was observed in frequent as opposed to infrequent video-game players, and the volume of this region was negatively correlated with deliberation time during the Cambridge Gambling Task. In the same region, frequent video-game players showed enhanced activity during feedback of loss compared to no loss, and this was negatively correlated with deliberation time in a Monetary Incentive Delay (MID) task. The extent to which these findings relate to other behavioral and substance addictions is unclear as individuals with alcohol dependence or pathological gambling have shown relatively diminished activation of the ventral striatum during the anticipatory phase of processing of monetary rewards (141, 142), whereas increased activation of reward-processing regions during reward outcome has been observed in cocaine dependence (143).

The function of other brain regions has been associated with video-game-playing. For example, among 19 healthy male adults playing a novel video-game for 60 minutes per day for 10 days, fMRI at the end of the 10-day period showed that internet-video-game stimuli versus neutral control stimuli more strongly activated the left inferior frontal gyrus, left parahippocampal gyrus, bilateral parietal lobes, thalamus and right cerebellum (113). In another study, adult males who spent more than 30 hours per week playing World of Warcraft (a MMOG) showed greater activation in the right orbitofrontal cortex (OFC), right nucleus accumbens, bilateral anterior cingulate, medial frontal cortex, right dorsolateral prefrontal cortex (dlPFC) and right caudate nucleus than “non-heavy Internet users” (less than 2 hours per day). These areas also positively correlated with self-reported gaming urge and recall of gaming experience provoked by World of Warcraft pictures (144). The above regions, specifically those in the limbic system, have also been implicated in IA. Adolescents with IA showed lower grey matter density in the left anterior cingulate cortex, left posterior cingulate cortex, left insula and left lingual gyrus than age- and gender-matched comparison subjects (145). Overall, abnormalities in the frontal cortex and the limbic system appear to play a role in both IA and PVG. Similar areas have also been linked to pathological gambling (44) and SUDs (146) including individuals with nicotine dependence (e.g. (147)) and heroin abuse/dependence (e.g. (148)) when presented with cues related to their substance of choice.

Specific genres relating to both IA and PVG may be associated with different neural correlates. For example, it has been hypothesized that video-game violence may desensitize users to real-world violence and increase aggression by removing normal inhibitions and aversive reactions to aggression (128, 149). In a study using electroencephalography (EEG), violent images evoked reduced P300 amplitudes among male undergraduates who self-reported playing more games with violent content and graphics as compared to those who self-reported low levels (150). fMRI data suggest that virtual violent scenes in video-games activate specific areas including mid-frontal brain regions, the temporoparietal junction and cerebellum, but deactivate limbic-orbitofrontal regions in male adults (151). While enhanced visual analysis and multisensory integration may explain the recruitment of some of these areas, the authors argued that lowered activity in some of these areas such as the rostral anterior cingulate cortex and amygdala may reflect suppressed affect processing and reduced "theory of mind." However, much of this research is in early stages and additional research, including direct comparison of different types of video-game material, is needed.

Currently, few studies have investigated the neurobiology of PVG or IA. Of those that do, more have focused on video-gaming (potentially due to their easier manipulation) with less neurobiological research in IA. In a developmental sense, it is unclear whether altered brain activity may be a precursor to or a result of PVG; how PVG may influence the development of the brain has yet to be investigated. Furthermore, with some exceptions (49), most studies predominantly or exclusively involve males, perhaps as they may represent a more convenient sample due to higher prevalence of PVG. Although similar brain activation in regions including the nucleus accumbens, OFC, dlPFC and insular cortex was found for a space-infringement game compared to a control task in both healthy adult male and female undergraduates, males generally exhibited greater activation and connectivity of the mesocorticolimbic reward circuitry than did females (152), suggesting potential gender-based differences.

A main problem with the existing neurobiological studies involves the lack of uniform criteria for or assessments of IA and PVG, making independent studies hard to compare. Most studies do not explicitly investigate pathological behavior; rather, frequent versus non-frequent users are often used as they provide a more convenient sample. An EEG study has provided some evidence in support of different neural processes of game-related cues for "casual" (average 0.25 hours game-play per day) versus "excessive" (average 4.31 hours game-play per day) video-game-playing adult men with the "excessive" players showing more addiction-like processing (153). However, it has been contended that a behavior only classifies as an addiction when it poses significant negative consequences, and this does not necessarily equate with excessive engagement (67, 112, 154, 155). Additionally, little is known about how other neurobiological factors that have been associated with addiction such as serotonin, endogenous opioids and stress hormones might relate to PVG and IA. As such, many questions remain regarding the neurobiology of IA or PVG.

Genetic features

Behavioral addictions such as pathological gambling have been shown to have heritable components; some of these are similar to those of SUDs and suggest a shared genetic vulnerability (23, 119, 156). In comparison, very little data currently exist for IA or PVG.

One study reported that the presence of the Taq1A1 allele of the dopamine D2 receptor (DRD2) and the low activity Val158Met variant of the Catecholamine-O-Methyltransferase (COMT) genes were more prevalent among 75 excessive Internet video-game-playing adolescent males (those who scored over 50 on Young's Internet Addiction Scale and reported playing Internet video-games more than 1 hour per day) than in 102 age- and

gender-matched control subjects (157). In particular, individuals with the DRD2 Taq1A1 allele scored higher on a reward-dependence scale. The relationship between the DRD2 Taq1A1 allele and SUDs has been debated. Although several studies have reported an association with some substance-related addictions including alcoholism (158), cocaine abuse (159) and pathological gambling (160), there have been mixed findings, reports of publication biases, and reports of linkage disequilibrium with other allelic variants (e.g., ANKK1) that may map more closely with addictive behaviors (161-165).

Another study focused on Internet use and allelic variants of the gene encoding the serotonin transporter (5HTTLPR) (166). Ninety-one male adolescents with excessive Internet use (those who scored over 50 on Young's Internet Addiction Scale and reported using the Internet more than 1 hour per day) were compared with 75 matched controls. The homozygous short allelic variant of the 5HTTLPR gene (SS-5HTTLPR) was reported to be more prevalent among the excessive Internet use group. Within this excessive use group, those with the SS-HTTLPR alleles showed higher harm avoidance and scored higher on Young's Internet Addiction Scale compared to those expressing other 5HTTLPR allelic variants. The SS-5HTTLPR has been associated with increased drug consumption (for review:(167)), particularly when exposed to stress (168, 169). Whether such a gene-by-environment interaction is also present in IA or PVG has yet to be investigated.

Currently little research has investigated the genetic features of PVG and IA. As such, genetic and epigenetic factors relating to IA and PVG should be examined further.

Treatment & Prevention

Most treatments for PVG have not been systematically examined. To date, there are very few published treatment approaches demonstrating empirical support. While video-games have been used therapeutically for other mental health disorders (170, 171), their potential in PVG should be considered cautiously. General practical advice and guidance for parents and practitioners have been described (e.g. (172)). Likewise, treatment for IA is based on interventions and general strategies to control for use (e.g. (173)). These typically include establishing suitable rules and guidelines for the users to ensure time for other activities, entering support groups and/or family therapy.

Behavioral

Cognitive Behavior Therapy (CBT) may help individuals address issues underlying problematic habits and assist them in helping them change their behaviors (174). CBT usually require 3 months of treatment and has been shown to be useful in reducing addictive behaviors including gambling (175) and cocaine use (176). Some have hypothesized that maladaptive cognitions such as negative core beliefs and cognitive distortions contribute to the compulsive use of the Internet (177, 178). To date, few studies have empirically examined the efficacy of using CBT for treating IA or PVG. Results from a 6-month CBT intervention involving 114 people with IA was reported to be effective in addressing negative core beliefs and cognitive distortions (179). CBT interventions included counseling focused on behavioral issues or underlying factors contributing to online abuse (e.g. marital discourse or academic troubles) and introducing strategies to control online use. Current use of the Internet was routinely assessed throughout the 6-month period and overall improvements and reduction in the number of IA symptoms was reported at the final assessment. This study, however, lacked a control group and did not evaluate the long-term efficacy of CBT. CBT has not been investigated in the treatment of PVG.

Pharmacological

Dopaminergic medications efficacious in the treatment of addictions may be helpful in treating PVG (88, 180). For example, bupropion, a drug with a weak inhibition of dopamine reuptake (181), has been investigated in the treatment of patients with addictions including cocaine dependence (182), nicotine dependence(183) and pathological gambling (184), with the strongest support (and FDA approval) for the treatment of nicotine dependence. When presented with Internet game cues (180), 11 Korean participants who in engaged in over 30 hours of online video-game play as compared to 8 healthy control subjects demonstrated greater brain activity within the occipital lobe, dlPFC and parahippocampal gyrus (180). After 6 weeks of bupropion treatment, decreased craving for Internet video-game play, total game-play time and activity of the dlPFC response to video-game cues was observed. As bupropion also has been shown to be efficacious in the treatment of depression, further investigation in PVG into potential mechanisms of action and clinical associations (e.g., with mood-related measures) is needed.

Associated Conditions

Possibly related health hazards, such as neck pain or repetitive strain injury, are likely to be relatively minor and temporary, resolving with decreased frequency of play or use. Therefore, treatment and prevention more directed towards reducing the ‘displacement’ of time and gaining control over the preoccupation with gaming or Internet use may be most clinically relevant. However, long-term studies are needed to examine this hypothesis, particularly as tendon- and joint-related illnesses such as carpal tunnel syndrome may develop over time.

Treatment Centers

There are some specialist addiction treatment clinics (e.g. in Korea, China, U.S.A.) specifically targeting video-gaming and Internet use addiction. For example, the recently opened inpatient treatment program named Restart Program in Redmond, Washington, U.S.A., provide a 45-day intensive care for individuals suffering from IA (185). Generally, programs tend to promote the abstinence model and incorporate aspects of family therapy (especially for child and adolescent patients) and social skills training into treatment. However, details of such therapeutic programs and the empirical support for the efficacies of the treatments they employ are not entirely clear (11, 186).

Conclusion

Research in PTU such as PVG and IA is still in its infancy. Emerging data suggest that both share similarities with SUDs, and both Internet use and video-game playing have the potential to become problematic or addictive. However, there are multiple existing research gaps. First, video-game-playing and Internet use are both heterogeneous. This heterogeneity may present a problem for generalizability, particularly with respect to considerations of prevention and treatment approaches. Contents of the Internet and video-games may differ on a range of dimensions and engage different cognitive, behavioral and affective systems, and thus may affect different processing systems. For example, some have hypothesized that specific features of some online games (e.g., the continuous time-flow that cannot be paused by the user) may create an environment that may be more problematic and/or more addictive than offline (single-player) games (172). Second, adolescent males have received the most research attention. As such, there is a relatively poorer understanding of how PVG and IA may affect females, and a poorer understanding of these processes in other age groups. Third, the lack of uniformly agreed-upon diagnostic criteria and assessment instruments is perhaps the biggest problem in the field. How these disorders are defined could significantly help understand the potential public health impacts of these behaviors.

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Table I

Selected Prevalence Studies of IA

Author and Year	Country	Sample	Assessment Instrument	Prevalence
Liu et al. (2011)	USA	*N* = 3,560 High school students Age 14-18	High School Risk Survey	4.0%
Johansson & Götestam (2004)	Norway	*N* = 3,237 Adolescents in general population Age 12-18	Young's Diagnostic Questionnaire (YDQ)	4.0% (among Internet users)
Ko et al. (2007)	Taiwan	*N* = 517 High school students Age 12-16	Chen's Internet addiction scale (CIAS)	7.5%
Yang et al. (2005)	South Korea	*N* = 328 High school students Age 15-19	Internet Addiction Test (IAT)	4.9%
Park et al. (2008)	South Korea	*N* = 903 Middle and high school students	Internet Addiction Test (IAT)	10.7%
Shek et al. (2008)	Hong Kong	*N* =6,121 Elementary and high school students Age 11-18	Chinese Internet Addiction (Goldberg) Scale & Chinese Internet Addiction (Young) Scale	19.1%
Aboujaoude et al. (2006)	USA	*N* = 2,513 Adults in General population Age ≥ 18	Telephone Survey	0.7%
Bakken et al. (2009)	Norway	*N* = 3,399 Adults in General population Age 16-74	Young's Diagnostic Questionnaire (YDQ)	1.0%
Niemz et al. (2005)	UK	*N* = 371 College students Age 21.5, SD = 5	Pathological Internet Use Scale	18.3%

Table II

Selected Prevalence Studies of PVG

Author and Year	Country	Sample	Assessment Instrument	Prevalence
Gentile (2009)	USA	*N* = 1,178 Adolescents in general population Age 8-18	11-item pathological-gaming scale developed by the authors	8.5% (among gamers)
Desai et al. (2010)	USA	*N* = 4,028 High school students Age 14-18	High School Risk Survey	4.9% (among gamers)
Johansson & Götestam (2004)	Norway	*N* = 3,237 Adolescents in general population Age 12-18	Pathological-gaming scale adapted from YDQ	4.2% (among gamers)
Griffith & Hunt (1998)	UK	*N* = 387 Adolescents in general population Age 12-16	Pathological-gaming scale adapted from DSM-III-R criteria for pathological gambling	20%
Grüsser et al. (2007	Germany	*N* = 7,069 General population Age 21.11, SD = 6.35	IA scale based on WHO's ICD-10 criteria of a dependence syndrome developed by the authors	11.9%