Computer and Video Game Addiction—A Comparison between Game Users and Non-Game Users

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Background: Computer game addiction is excessive or compulsive use of computer and video games that may interfere with daily life. It is not clear whether video game playing meets diagnostic criteria for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). Objectives: First objective is to review the literature on computer and video game addiction over the topics of diagnosis, phenomenology, epidemiology, and treatment. Second objective is to describe a brain imaging study measuring dopamine release during computer game playing. Methods: Article search of 15 published articles between 2000 and 2009 in Medline and PubMed on computer and video game addiction. Nine abstinent “ecstasy” users and 8 control subjects were scanned at baseline and after performing on a motorbike riding computer game while imaging dopamine release in vivo with [123I]IBZM and single photon emission computed tomography (SPECT). Results: Psycho-physiological mechanisms underlying computer game addiction are mainly stress coping mechanisms, emotional reactions, sensitization, and reward. Computer game playing may lead to long-term changes in the reward circuitry that resemble the effects of substance dependence. The brain imaging study showed that healthy control subjects had reduced dopamine D2 receptor occupancy of 10.5% in the caudate after playing a motorbike riding computer game compared with baseline levels of binding consistent with increased release and binding to its receptors. Ex-chronic “ecstasy” users showed no change in levels of dopamine D2 receptor occupancy after playing this game. Conclusion: This evidence supports the notion that psycho-stimulant users have decreased sensitivity to natural reward. Significance: Computer game addicts or gamblers may show reduced dopamine response to stimuli associated with their addiction presumably due to sensitization.

Keywords: addiction, brain imaging, computer game playing, dopamine, reward, video game playing

INTRODUCTION

Problem Definition

Computer or video game addiction is excessive or compulsive use of computer and video games that interferes with daily life. Users may play compulsively, isolating themselves from other forms of social contact, and focus almost entirely on in-game achievements rather than broader life events.

Griffiths (1) has operationally defined addictive behavior as any behavior that features what he believes are the six core components of addiction (i.e., salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse). He further argued that video game addiction fulfils the criterion of addiction by virtue of meeting these criteria. In his view, since many video game users are excessive users and not addicts, video game addiction may be a medium for satisfaction of arousal and reward (see section on mechanisms of reward). In addition to the neurochemical basis for addiction, there are accompanied behavioral markers of dependence in adolescents such as stealing, truancy, not doing homework, irritability if unable to play, etc. Finally, single case studies have shown the video game addiction was used in order to compensate for deficiencies in one’s life in areas such as interpersonal relationships, physical appearance, disability, coping, etc. Griffiths (2) argued that although there are educational, social, and therapeutic benefits to video games play, taken in excess they could lead to addiction, playing 24 hours a day 7 days a week and in some cases to a gambling problem. Finally, Griffiths (3) concluded that adverse effects of video game addiction are relatively minor and temporary resolving spontaneously with decreased frequency of play or to affect a small group of players.

There is no evidence for genetic factors influencing video or computer game addiction. Most studies describe a behavior that is independent of other psychiatric disorders (e.g., not just secondary to another condition such as attention deficit hyperactivity disorder [ADHD] or mania). There is a single study suggesting co-morbidity with depression (4) and for comorbidity with ADHD (5) but there is no evidence for co-morbidity with substance use disorder. On the spectrum of impulsivity and obsessive-compulsive behavior, there is some evidence for impulsivity on the Barrat Impulsivity scale (4), and excessive computer and video game playing supports the notion of obsessive-compulsive behavior although formal assessment of obsessive-compulsive behavior in these individuals has not been...
done. According to Griffiths (6) case studies of individuals who use the Internet excessively may also provide better evidence of whether Internet addiction exists, because the data collected are much more detailed than data from surveys. Case studies can highlight the role of context in distinguishing excessive gaming from addictive gaming and can demonstrate that excessive gaming does not necessarily mean that a person is addicted. It is argued that online gaming addiction should be characterized by the extent to which excessive gaming impacts negatively on other areas of the gamers’ lives rather than the amount of time spent playing. It is also suggested that an activity cannot be described as an addiction if there are few (or no) negative consequences in the player’s life even if the gamer is playing 14 hours a day (7).

Currently, it is not clear whether video game playing meets criteria for a syndrome, e.g., Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) or ICD-10 definition of a clinically significant pattern (consistent co-occurrence and time course) of behavioral and psychological signs and symptoms that cause distress or impairment. In 2007, the American Psychiatric Association reviewed whether or not video game addiction should be added to the new DSM to be released in 2012. The conclusion was that there was not enough evidence to warrant the inclusion of computer game addiction as a disorder.

DIAGNOSIS AND PREVALENCE

The diagnostic assessment of internet or computer game dependency remains problematic. Different studies in different countries have used different scales to assess prevalence of computer game addiction. A national Harris Poll survey of 1,178 U.S. youths ages 8–18 years found that 8.5% of computer gamers were pathological players according to standards established for pathological gambling (Harris Interactive, 2007). Among 323 German children ranging in age from 11 to 14 years, 9.3% (N = 30) met criteria for dependency and pathological gaming using DSM-IV and ICD-10 criteria (8). A second study of 7069 computer-game players reported that 11.9% met three of the diagnostic criteria for addiction (9). Finally, among 221 computer game players, 6.3% have met ICD-10 criterion of addiction (10). Among 2327 Norwegian youth, 2.7% (4.2% of the boys, 1.1% of the girls) fulfilled the criteria for pathological playing following a “Diagnostic Questionnaire for Internet Addiction of Young;” 9.8% (14.5% of the boys, 5% of the girls) were considered to be engaging in “at risk playing” (11). In the United Kingdom, a survey of 387 adolescents (12–16 years of age) found that 20% met computer dependence using a scale adapted from the DSM-III-R criteria for pathological gambling (12). A German National survey of 7000 gamers found that 12% met three of the criterion for internet addiction (9). Results of a German nationwide survey of 44,610 male and female ninth-graders in 2007 and 2008 have shown that 3% of the male and 3% of the female students were diagnosed as dependent on video games. Video game dependency (VGD) was accompanied by increased levels of psychological and social stress in the form of lower school achievement, increased truancy, reduced sleep time, limited leisure activities, and increased thoughts of committing suicide. In addition, it becomes evident that personal risk factors were crucial for VGD (13). Finally, a survey of 3,975 Turkish undergraduate students found that the most preferred type of game was violent games; while preference for strategy and fantasy role-play games has increased with age, preference for other games has decreased (14).

This review searched articles published between 2000 and 2009 in Medline and PubMed using the key word computer and video game addiction over the topics of diagnosis, phenomenology, epidemiology, and treatment.

WHY DO PEOPLE BECOME ADDICTED TO COMPUTER GAME PLAYING?

Although repetition of favorite activities has a moderate effect upon computer game addiction, flow experience, the emotional state embracing perceptual distortion and enjoyment shows a strong impact on addiction in Taiwanese players (15). Responses of computer game players in Taiwan have qualitatively reflected their psychological needs and motivations in daily life, but also to the interplay of real self and virtual self, compensatory, or extensive satisfaction for their needs and self-reflections (16). Social relationships and the specific time and flexibility characteristics (“easy-in, easy-out”) in multiplayer browser games have been suggested as the main cause for enjoyment in Germany (17). Game and internet addictions are also connected with interpersonal relationship patterns (18). Competition, in contrast, seems to be less important for browser gamers than for users of other game types. There is only weak evidence for the assumption that aggressive behavior is associated with excessive gaming (9). Excessive computer game playing could result in deficient visual-spatial ability (19).

HEALTH HAZARDS

The medical profession, for over 20 years, has voiced a number of concerns about video game playing. Back in the early 1980s, rheumatologists described cases of “Pac-man’s Elbow” and “Space Invaders’ Revenge” in which players have suffered skin, joint, and muscle problems from repeated button hitting and joystick pushing on the game machines (20). Early research by Loftus and Loftus indicated that two-thirds of (arcade) video game players examined complained of blisters, calluses, sore tendons, and numbness of fingers, hands, and elbows directly as a result of their playing. There have been a whole host of case studies in the medical literature reporting some of the adverse effects of playing video games (21, 22). These have included auditory hallucinations (23), enuresis (24), encopresis (25), wrist pain (26), neck pain (27), elbow pain (27), tenosynovitis—also called “nintendinitis” (28–31), hand-arm vibration syndrome (32), repetitive strain injuries (33), and peripheral
neuropathy (34). Recently, there is a study describing ten patients who experienced epileptic seizures while playing the newest genre of electronic games Massively Multiplayer Online Role-Playing Games (MMORPGs) (35). Patients were predominantly young, male adults, and most of the events were generalized tonic-clonic seizures, myoclonic seizures, and absences. The author suggested that while the prevalence of MMORPG-induced seizures remains unknown, there should be an awareness of this special form of reflex seizures in order to provide an appropriate health warning to MMORPG players.

**PREVENTION AND TREATMENT**

There is preliminary evidence for success of an “initiated abstinence” program in 12–15 year old pupils in Austria, Germany, and Italy (36). Some countries like the United States, Canada, China, Korea, and the Netherlands have opened treatment centers for video game addiction. In 2009, ReSTART has set up a residential treatment center in Seattle, WA for pathological internet use. There is little evidence for psychological or pharmacological treatment for video and computer game addiction. A study using methylphenidate in 62 Korean children diagnosed with ADHD and internet video game addiction was reported (2). After 8 weeks of treatment, measures of internet use scores and internet usage times were significantly reduced, and these measures were positively correlated with measures of attention. The authors suggest that internet video game playing might be a means of self-medication for children with ADHD. In addition, they cautiously suggest that Methylphenidate (MPH) might be evaluated as a potential treatment of Internet addiction. In summary, there are very few clinical trials and no meta-analyses on treatment for excessive computer game addiction.

**MOTORBIKE-RIDING COMPUTER GAME FOR QUANTIFYING DOPAMINE RELEASE: RATIONAL AND AIMS OF THE STUDY**

Chronic use of psycho-stimulants such as cocaine and methamphetamine results in long-term effects to the dopamine reward system. For example, compared to healthy subjects, detoxified cocaine-dependent subjects exhibit reduced striatal D2 receptor availability (37–39) and decreased drug-induced dopamine release (39, 40). Currently, there is evidence that abstinent “ecstasy” users with a history of using sequential “ecstasy” doses had no reductions in striatal dopamine transporter (DAT) binding (41). Since other stimulant drug abusing populations show evidence of diminished dopamine responsiveness we have decided to test whether this observation extends to “ecstasy” abusers in response to a non-drug reward/challenge. We hypothesized that chronic use of “ecstasy,” similar to other psycho-stimulants such as cocaine and methamphetamine might result in long-term changes to the dopaminergic reward system. The effects of “ecstasy”-induced alterations on the dopamine reward circuit (basal ganglia-thalamo-cortical circuit) are potentially secondary to the neurotoxic effects of “ecstasy” on 5-HT signaling.

We, therefore, decided to investigate dopamine release in the brain during playing of a motorbike riding computer game. Because some subjects were former chronic users of MDMA (“ecstasy”), we were also able to evaluate whether past chronic use of “ecstasy” had any long-term effects on game performance, levels of dopamine receptor occupancy, or dopamine release in the striatum during game playing. Unfortunately, our study did not include computer game players since our grant was limited to investigate drug addiction.

**BEHAVIORALLY-INDUCED DOPAMINE-RELEASE IN THE BRAIN’S REWARD SYSTEM**

The quantification of dopamine release in the human brain is now possible due to brain imaging techniques that measure dopamine D2 receptor availability in human subjects using dopamine competition with either [123I] IBZM (a D2 receptor antagonist radiotracer) in single photon emission computed tomography (SPECT) (42) or [11C] raclopride in positron emission tomography (PET). Either [123I] IBZM or [11C] raclopride binding is sensitive to endogenous DA concentration; this procedure can also be used to measure relative changes in DA concentration secondary to pharmacological or behavioral interventions. Playing a computer tank riding game can release dopamine in vivo in the human brain comparable to the dopamine released as a result of pharmacological challenge with amphetamines (43). Behavioral paradigms, such as playing a video game (43), monetary reward tasks (44), and non-hedonic food motivation (45) also release dopamine in brain meso-limbic reward centers.

**PROCEDURE**

**Subjects**

Nine former “ecstasy” users (mean age 25 years (SD = 3.5); 8 males, 1 female) verified abstinent up to 1.5 years (mean = 5 months, range 1–18 months) and eight control subjects (mean age 35.75 years(SD = 6.5); 7 males, 1 female). Former “ecstasy” users had less education (12 (.9) years) than control subjects (13.75 (1.6) years). Ex-“ecstasy” users used on average 220 “ecstasy” tablets (range 30–600) in their life, and total number of tablets in their lifetime was 428.5 (range 30–1500). They used “ecstasy” on average for 12 years and 3 months (SD = .92). They reported on average 7 times of using “ecstasy” in a month during their last year of use before treatment (SD = 3.3) and time since last use was on average 5 months (range 1–18 months). A list of all substances used by ex-“ecstasy” users is presented in Table 1.

The former “ecstasy”-users, recruited from drug treatment centers. Control subjects were recruited through advertisement in treatment centers and the hospital. They reported no current or recent use of “ecstasy” or marijuana. Five of the ex-“ecstasy” patients were treated with antidepressant medication (Sertraline,
Table 1. List of drugs and alcohol use among ex-“ecstasy” users.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarettes (per day)</td>
<td>17</td>
<td>6.75</td>
<td>5–30</td>
</tr>
<tr>
<td>Alcohol units per week</td>
<td>2.95</td>
<td>2.54</td>
<td>0–9</td>
</tr>
<tr>
<td>Amphetamines: lifetime number of tablets</td>
<td>2.8</td>
<td>4</td>
<td>0–10</td>
</tr>
<tr>
<td>Cocaine: lifetime number of times used</td>
<td>25</td>
<td>3.6</td>
<td>0–50</td>
</tr>
<tr>
<td>L.S.D.: lifetime number of tablets</td>
<td>75</td>
<td>80</td>
<td>0–500</td>
</tr>
<tr>
<td>Marijuana: number of cigarettes per day</td>
<td>11.8</td>
<td>11</td>
<td>1–30</td>
</tr>
<tr>
<td>Inhalants</td>
<td>20.8</td>
<td>62</td>
<td>0–200</td>
</tr>
<tr>
<td>Opiates: number of times used</td>
<td>2.4</td>
<td>3</td>
<td>0–8</td>
</tr>
<tr>
<td>PCP</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magic mushrooms: lifetime number of use</td>
<td>9.4</td>
<td>16</td>
<td>0–50</td>
</tr>
</tbody>
</table>

Venlafaxine, Fluoxetine, and Escitalopram and six of them were treated with relaxants (Clonazepam and Diazepam). They were scanned six months after treatment when they were not taking medication.

Behavioral Computerized Game

Commercially available motorbike-riding computerized video game by “motogp” ultimate racing technology (www.THQ.co.uk) using a joystick. The time it took to complete each track on the racing field was recorded on the computer.

Procedure

Eligible subjects gave written informed consent and were admitted to the hospital at 10 a.m. Starting at 10:30 a.m., they received a bolus injection of 5–6 mCi of [123I] IBZM, followed by constant infusion of 5–6 mCi of [123I] IBZM (1.7–2 mCi/hr for three hours while resting on a hospital bed. Due to problems with radiation safety in our brain imaging facility, we were not able to continue with constant infusion beyond 3 hours postinjection. We are not aware of any literature precedents for using an altered [123I] IBZM infusion protocol like ours. In healthy volunteers who were injected with bolus [123I] IBZM without constant infusion, pseudo-equilibrium was achieved at 90 min postbolus injection of [123I] IBZM, and it was maintained until the end of the SPECT session at 3 hours postinjection (46). In our study, due to the termination of constant infusion after 3 hours, there is a possibility of a higher rate of washout of the tracer from the plasma, which might have affected the results. However, there is evidence that postinfusion equilibrium is maintained, and the washout rate of the tracer from the plasma may have been minimal, and it may have not affected our results (47). After a baseline SPECT scan, they returned to their room and played the motorbike-riding computer game for 40 minutes. After game playing, they had a second SPECT scan, followed after 15 minutes of rest by a third SPECT scan.

Image Analysis

A measure of dopamine receptor occupancy obtained without plasma measurements is the specific to nonspecific equilibrium partition coefficient, $V_3''$, which is a measure of dopamine D2 receptor availability and can be calculated from: $V_3'' = (S - O)/O$, where S and O are activity concentrations in the striatum and occipital cortex, respectively (42). This calculation has been shown to give accurate values of $V_3''$ under equilibrium conditions. Its accuracy is not known under the conditions of this study, where infusion was stopped before the first scan. All images were registered and normalized to an IBZM template (48) using the preprocessing tools of Statistical Parametric Mapping (SPM). The image comparisons were then performed using the MarsBaR tool within SPM.

RESULTS

First, at baseline, there was no significant difference in D2 receptor occupancy, i.e., partition coefficient ($V_3''$), in abstinent “ecstasy” users compared with control subjects (.71 and .86, respectively). Second, during performance of the video game, there was a 10.5% reduction, compared to baseline, in the partition coefficient ($V_3''$) in control subjects in the caudate, consistent with increased dopamine release and binding to the D2 receptors. In control subjects, there were lower rates of binding potential after motorbike riding game compared with baseline (scan 1 versus scan 2) in the right caudate $t(1,7) = 2.56; p < .05$. There was no reduction in the abstinent “ecstasy” users after performance of the video game in all parts of the striatum. Third, D2 receptor levels have not returned to baseline after the third scan in control subjects consistently with results reported by a previous study (22). Fourth, there was significant correlation between performance measures (reaction time on the video game) of all subjects and baseline measures of binding potentials (scan 1) in the right caudate ($r = .70; p < .001$), left caudate ($r = .67; p < .01$), right putamen ($r = .68; p < .01$), and left putamen ($r = .72; p < .001$). Finally, there was no difference
in performance (reaction-time) between the two groups on the motorbike video game.

Figure 1 shows measures of partition coefficient (V3") in control subjects and abstinent “ecstasy” patients in the caudate and putamen divided by laterality in all scans (1, 2, and 3).

Table 2 shows average V3’ measures and standard deviations in the caudate putamen in control subjects and ex-“ecstasy” users in all scans.

**DISCUSSION**

Control subjects had significant 10.5% reduction in binding potential measure in the caudate after performance compared with their baseline measure, consistent with the results reported by a previous study (43) that showed 13% reduction of binding potential in the ventral striatum after video game performance. This is comparable to measures of dopamine release produced by amphetamine (49) or methylphenidate (50, 51). This
TABLE 2.
Average V" measures in the caudate putamen in control subjects and ex-"ecstasy" users in all scans.

<table>
<thead>
<tr>
<th>Left caudate</th>
<th>Scan 1</th>
<th>Scan 2</th>
<th>Scan 3</th>
<th>Right caudate</th>
<th>Scan 1</th>
<th>Scan 2</th>
<th>Scan 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>.64</td>
<td>.53</td>
<td>.44</td>
<td>mean</td>
<td>.75</td>
<td>.65</td>
<td>.56</td>
</tr>
<tr>
<td>SD</td>
<td>.29</td>
<td>.26</td>
<td>.17</td>
<td>SD</td>
<td>.36</td>
<td>.29</td>
<td>.23</td>
</tr>
<tr>
<td>Ex-&quot;ecstasy&quot;</td>
<td>.53</td>
<td>.50</td>
<td>.48</td>
<td>mean</td>
<td>.61</td>
<td>.59</td>
<td>.54</td>
</tr>
<tr>
<td>SD</td>
<td>.36</td>
<td>.29</td>
<td>.23</td>
<td>SD</td>
<td>.36</td>
<td>.29</td>
<td>.23</td>
</tr>
<tr>
<td>Left putamen</td>
<td>Scan 1</td>
<td>Scan 2</td>
<td>Scan 3</td>
<td>Right putamen</td>
<td>Scan 1</td>
<td>Scan 2</td>
<td>Scan 3</td>
</tr>
<tr>
<td>Control</td>
<td>.95</td>
<td>.88</td>
<td>.71</td>
<td>mean</td>
<td>1.10</td>
<td>1.00</td>
<td>.84</td>
</tr>
<tr>
<td>SD</td>
<td>.40</td>
<td>.36</td>
<td>.30</td>
<td>SD</td>
<td>.44</td>
<td>.36</td>
<td>.28</td>
</tr>
<tr>
<td>Ex-&quot;ecstasy&quot;</td>
<td>.80</td>
<td>.79</td>
<td>.78</td>
<td>mean</td>
<td>.91</td>
<td>.92</td>
<td>.84</td>
</tr>
<tr>
<td>SD</td>
<td>.26</td>
<td>.17</td>
<td>.29</td>
<td>SD</td>
<td>.25</td>
<td>.20</td>
<td>.26</td>
</tr>
</tbody>
</table>

finding implies that video game playing is capable of significant dopamine release that is comparable to the effects of psycho-stimulant drugs on the brain. It is plausible that individuals who are addicted to video-game playing derive much pleasure from playing these games due to extensive dopamine release. In contrast, former "ecstasy" users showed little change in D2 binding potential in the caudate/putamen in response to video game performance. This finding implies low brain dopamine response to natural reward presumably due to previous sensitization to stimulant drugs that release a great amount of dopamine in their brain over time.

The finding of correlation between reaction time measurements and the baseline scan V" for both cohorts merits further consideration. Our findings suggest that there was no effect of game playing on changes in V" in ex-"ecstasy" users, even though their reaction times like comparison subject reaction times were correlated with baseline scan V". These findings taken altogether may imply at least a partial dissociation between the reward and motor system consequences of "ecstasy" use.

There are several limitations to our study. First, our ex-"ecstasy" patients have used other drugs than "ecstasy," which may have affected measures of binding potential especially in the case of marijuana. Secondly, most ex-"ecstasy" users have been treated with Selective Serotonin Reuptake Inhibitors (SSRIs) or relaxant medication (benzodiazepines), and these medications are known to interact with the dopamine system, although they were not medicated during scanning. Thirdly, the ex-"ecstasy" users were younger than control subjects, but that would only mean that their dopamine receptor occupancy should be higher than control subjects (dopamine transporter availability measures decline about 6.6% every 10 years) (52). Fourthly, since there was only one female subject in each group, and they were both pre-menopausal, this may have affected the results, but there is no evidence for any menstrual-cycle-dependent variation in D2 receptor density detectable with single PET [11C] Raclopride (53). Fifthly, the second and third scans were not performed under ideal conditions of equilibrium, and this may have affected the results due to higher rates of washout. Finally, this is a small sample even for a brain imaging study due to strict selection criteria.

OVERALL DISCUSSION

Computer or video game addiction, which is excessive or compulsive use of computer and video games with resulting adverse consequences, is not clinically defined as a part of behavioral addictions in DSM-IV. There is no official diagnosis or definition of the disorder in any official diagnostic system. There were several studies investigating the prevalence of this disorder; however, they used different scales adapted from the DSM-III-R criteria for pathological gambling or other addictions to create diagnostic questionnaires. People like computer game playing and become addicted to it due to repetition of favorable activities or emotional experiences, experiences of fulfillment, social relationship, and flexibility, while the aspects of competition and aggression have been discounted.

Three different mechanisms have been suggested as driving excessive computer gaming, although there have been very few psycho-physiological investigations of these underlying mechanisms. First, it has been suggested that computer games are inadequate means of coping with frustration, stress, and fears.
The excessive usage of computer and video games is seen as a rewarding behavior which can, due to learning mechanisms, become a prominent and inadequate strategy for 11 to 14 year old children to cope with negative emotions like frustration, uneasiness, and fears. Like substance abuse or addiction, excessive computer and video game players use their excessive rewarding behavior specifically as an inadequate stress coping strategy. It is also known that computer game addiction decreased the quality of interpersonal relationships and the amount of social anxiety increased as the amount of time spent playing online games increased (54). Secondly, and consistent with the stress-coping explanation, it has been suggested that in-game reinforcement and skill significantly influence a number of affective measures, most notably excitement, arousal, and frustration (55). Thirdly, excessive computer game playing may be maintained through effects on reward and sensitization (56), similar to the long-term changes in the brain reward circuitry thought to maintain substance dependence. Electroencephalographic recordings in computer game players have shown increased emotional processing of computer-related cues in parietal brain regions in pathologically excessive players compared with casual players. Furthermore, when participants with online game addiction were presented with gaming pictures and mosaic control pictures while undergoing functional magnetic resonance imaging (fMRI), they have shown activation of the brain’s craving areas including the right orbito-frontal cortex, right nucleus accumbens, bilateral anterior cingulate and medial frontal cortex, right dorso-lateral prefrontal cortex, and right caudate nucleus (57). Thus, the results suggest that the gaming urge/craving in online gaming addiction and craving in substance dependence might share the same neurobiological mechanism.

Finally, in a functional Magnetic Resonance Imaging (fMRI) study contrasting a space-infringement game with a control task, males showed greater activation and functional connectivity compared to females in the meso-cortico-limbic system (58). These findings may be attributable to higher motivational states in males, as well as gender differences in reward prediction, learning reward values, and cognitive state during computer video game playing. These gender differences may help explain why males are more attracted to, and more likely to become “hooked” on video games.

The reward and sensitization explanation is consistent with growing evidence that computer game playing addiction, similar to other behavioral addictions like compulsive gambling, overeating, sex, and shopping, leads to long-term changes in the reward circuitry that resemble the effects of substance dependence. Advanced brain imaging techniques using the dopamine-competition paradigm can quantify dopamine release as result of computer game playing. So far, playing computer games in healthy volunteers has shown dopamine release in the striatum to a similar extent as pharmacological challenge, whereas we have shown that former chronic users of ecstasy released very little dopamine after performance of a computer game. We speculate that, similar to psycho-stimulant abusers, individuals diagnosed with behavioral addictions such as gambling and computer game addiction would show reduced dopamine release after performance of video games or gambling presumably due to sensitization. Future research could investigate these individuals and could give a psycho-biological explanation to this emerging object of scientific research.

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Declaration of Interest

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