European Psychiatry xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

European Psychiatry

journal homepage: http://www.europsy-journal.com

Original article

Cognitive control and reward/loss processing in Internet gaming disorder: Results from a comparison with recreational Internet game-users

Q1 G. Dong [a,b,*], H. Li [a], L. Wang [a], M.N. Potenza [c,d,**]

Q2 [a] Department of Psychology, Zhejiang Normal University, Jinhua, Zhejiang Province, PR China
[b] Institute of Psychological and Brain Sciences, Zhejiang Normal University, Jinhua, Zhejiang Province, PR China
[c] Department of Psychiatry, Department of Neurobiology, Child Study Center, and National Center on Addiction and Substance Abuse, Yale University School of Medicine, 06519 New Haven, CT, USA
[d] Connecticut Mental Health Center, New Haven, CT, USA

ARTICLE INFO

Article history:
Received 17 November 2016
Received in revised form 27 February 2017
Accepted 12 March 2017
Available online xxx

Keywords:
Recreational Internet game use
Internet gaming disorder
Executive control
Reward/punishment sensitivity

ABSTRACT

Although playing of Internet games may lead to Internet gaming disorder (IGD), most game-users do not develop problems and only a relatively small subset experiences IGD. Game playing may have positive health associations, whereas IGD has been repeatedly associated with negative health measures, and it is thus important to understand differences between individuals with IGD, recreational (non-problematic) game use (RGU) and non-/low-frequency game use (NLFGU). Individuals with IGD have shown differences in neural activations from non-gamers, yet few studies have examined neural differences between individuals with IGD, RGU and NLFGU. Eighteen individuals with IGD, 21 with RGU and 19 with NFLGU performed a color-word Stroop task and a guessing task assessing reward/loss processing. Behavioral and functional imaging data were collected and compared between groups. RGU and NLFGU subjects showed lower Stroop effects as compared with those with IGD. RGU subjects as compared to those with IGD demonstrated less frontal cortical activation brain activation during Stroop performance. During the guessing task, RGU subjects showed greater cortico-striatal activations than IGD subjects during processing of winning outcomes and greater frontal brain during processing of losing outcomes. Findings suggest that RGU as compared with IGD subjects show greater executive control and greater activations of brain regions implicated in motivational processes during reward processing and greater cortical activations during loss processing. These findings suggest neural and behavioral features distinguishing RGU from IGD and mechanisms by which RGU may be motivated to play online games frequently yet avoid developing IGD.

1. Introduction

Unlike substance addictions, no chemical intake is needed for Internet gaming disorder (IGD), which has led to IGD being Q3 conceptualized as a behavioral addiction [1–6]. Consistent with this classification, IGD has demonstrated neurobiological similarities to substance-use and gambling disorders [7–11]. In 2013, the DSM-5 committee considering substance-use and addictive disorders generated criteria for IGD, and this condition is included in section 3 of the DSM-5 containing disorders warranting additional study [4,5,12,13].

Only a relatively small group of individuals who play online games develop IGD, with a majority demonstrating abilities to control game-playing behaviors without developing problems [14–17]. Individuals who report recreational game use (RGU) may play online games regularly without experiencing a loss of control or exhibiting cravings for gaming. Some data suggest that regular gaming is not associated with negative health measures and may be associated with positive health measures, particularly amongst boys [18]. For example, a meta-analysis did not observe significant associations between playing video games and measures of mental health, aggression or other assessed domains [19], although this

* Corresponding author. Department of Psychology, Zhejiang Normal University, 688 Yingbin Road, Jinhua, Zhejiang Province, PR China. Tel.: +86 158 679 499 09.
** Corresponding author. Department of Psychiatry, Yale University School of Medicine; Connecticut Mental Health Center, Room S 104, 34 Park Street, 06519 New Haven, CT, USA.
E-mail addresses: dongguangheng@zjnu.edu.cn (G. Dong), marc.potenza@yale.edu (M.N. Potenza).

http://dx.doi.org/10.1016/j.eurpsy.2017.03.004
0924-9338/

topic remains controversial [20,21]. Investigators have posited that videogames may potentially enhance cognitive function, although this possibility warrants additional study [22]. Additionally, studying groups of individuals with RGU may provide insight into measures protecting individuals from IGD, given the level of exposure to gaming that individuals with RGU may experience [23]. As such, it is important to study varying levels of gaming, including IGD, RGU and non-/low-frequency gaming use (NLFGU).

When considering RGU, it is helpful to consider recreational levels of other potentially addictive behaviors like substance use and gambling. Groups of individuals with recreational drug use or gambling have shown differences from abstinent and addicted groups. Recreational cocaine users have shown decreased discounting of delayed rewards compared with individuals with cocaine dependence [24], suggesting a relatively lower level of impulsivity among recreational users. Another study revealed that unlike dependent stimulant users, recreational cocaine users did not show drug-related attentional biases and displayed a unique pattern of activation during performance of a drug Stroop task, demonstrating less activation in the orbitofrontal and anterior cingulate cortices compared with both dependent users and control subjects [25]. In some ways, recreational users fall between stimulant-dependent and non-using individuals in terms of behavioral and neurocognitive responses, and this may reflect a greater familiarity with stimulant cues with respect to the non-using group and more controlled use with respect to the dependent group [24,25]. With respect to gambling, recreational gambling has shown evidence of relationships to psychopathology intermediate between non-/low-frequency gambling and problem pathological gambling [18,23,26,27], suggesting associated health impairments may extend to subsyndromal levels of gambling.

Although individuals with RGU may show intermediate characteristics between those with IGD and NLFGU, they may also show similar or distinguishing characteristics relating to each group. For example, individuals with RGU may have similar patterns of drive to engage in game playing as compared with those with IGD (differing from the NLFGU group), and they may have greater self-control over gaming (as compared with the IGD group). Thus, considering behavioral control and reward/loss processes are important in understanding RGU as compared with IGD and NLFGU.

Inhibitory control may protect individuals with RGU from developing IGD [1,28]. Individuals with IGD have been documented to demonstrate poor impulse control [29,30–32]. Studies have showed abnormal brain responses in frontal brain regions in IGD subjects (as compared to those without) when performing inhibitory control tasks [33–35], consistent with findings regarding prefrontal cortical dysfunction in substance addictions [36–38]. Thus, one might hypothesize that individuals with RGU (as compared to those with IGD) may exhibit better executive control and that this might relate to prefrontal cortical functioning.

Another important domain in the pathophysiology of addiction involves reward/loss processing [39,40]. Studies suggest enhanced reward sensitivity and decreased loss sensitivity in IGD subjects [28,41–43]. An enhanced sensitivity to rewards may promote game playing in IGD, while a decrease in sensitivity to losses may relate to diminished worrying about negative consequences relating to gaming. Thus, it is feasible that individuals with RGU (as compared to those with IGD) may show differences in reward and/or loss processing, as reflected in cortico-striatal neural systems linked to reward/loss processing.

In the current study, we set to investigate cognitive control using a color-word Stroop task and reward/loss processing using a guessing task in individuals with IGD, RGU or NLFGU. Studies of recreational cocaine users show intermediate characteristics between those with addictions and non-use, similar to the amount of cocaine used in the different groups [24]. Differences in individuals with occasional as opposed to addictive drug use also extend to tobacco use. For example, studies of occasional smokers have shown enhanced brain activity in reward-related brain regions when processing monetary rewards relative to cigarette rewards [44], and impulsivity has been positively associated with tonic craving for daily but not occasional smokers [45,46]. However, in IGD, RGU, and NLFGU, a difference might involve the amount of time spent playing videogames. However, the amount of time does not *equate per se* to the severity of IGD. Thus, a main focus of the current study involved the comparison between individuals with RGU and IGD. A NLFGU group was included to examine the extent to which prior findings were replicated and to place the findings within the larger literature. To our knowledge, this is the first study investigating the specific behavioral and neural features of IGD, RGU and NLFGU together. Given the data discussed above, we hypothesized that IGD as compared with RGU individuals would show poorer cognitive control and that this would link to prefrontal cortical function. We also hypothesized that individuals with IGD would show differences from those with RGU and NLFGU in the neural correlates of reward/loss processing in prefrontal cortical and striatal regions.

2. Methods and materials

2.1. Participant selection

The experiment conforms to The Code of Ethics of the World Medical Association (Declaration of Helsinki). The Human Investigations Committee of Zhejiang Normal University approved this research. Participants were university students and were recruited through advertisements. We assessed 18 individuals with IGD, 21 with RGU, and 19 with NLFGU; all were university students from the East China Normal University. There were no significant differences in age among the three groups (F (2, 56) = 0.21, P = 0.81) (Table 1). All participants were right-handed males. Only males were included due to higher IGD prevalence in men than in

Table 1
Demographic information and group differences.

	IGD n = 18	RGU n = 21	NFLGU n = 19	F	P
Age (mean ± SD)	21 ± 2.83	22 ± 2.45	21 ± 3.67	0.21	0.81
BDI score (mean ± SD)	2.66 ± 0.36	1.89 ± 0.24	1.35 ± 0.20	0.18	0.68
IAT score (mean ± SD)	79.50 ± 0.71	32.48 ± 4.59	26.20 ± 5.26	29.02	0.000***
DSM-5 score (mean ± SD)	7.5 ± 0.71	2.62 ± 1.60	0.6 ± 0.89	15.56	0.000***
Years playing online games (mean ± SD)	1.75 ± 0.25	2.2 ± 0.53	0.83 ± 0.22	0.64	0.034*
Game playing per week (hours) (mean ± SD)	24.6 ± 2.86	19.52 ± 2.09	2.2 ± 1.64	21.15	0.000***

IGD: Internet gaming disorder; RGU: recreational game use; NFLGU: non-/low-frequency game use.
* $P < 0.05$.
*** $P < 0.001$.

Please cite this article in press as: Dong G, et al. Cognitive control and reward/loss processing in Internet gaming disorder: Results from a comparison with recreational Internet game-users. European Psychiatry (2017), http://dx.doi.org/10.1016/j.eurpsy.2017.03.004