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Risk-taking and risky decision-making in Internet gaming disorder: Implications regarding online gaming in the setting of negative consequences

Guangheng Dong [a,*], Marc N. Potenza [b]

[a] Department of Psychology, Zhejiang Normal University, Jinhua, Zhejiang Province, PR China
[b] Department of Psychiatry, Child Study Center, CASAColumbia, Yale University School of Medicine, New Haven, CT, USA

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ABSTRACT

Individuals with Internet gaming disorder (IGD) continue gaming despite adverse consequences. However, the precise mechanism underlying this behavior remains unknown. In this study, data from 20 IGD subjects and 16 otherwise comparable healthy control subjects (HCs) were recorded and compared when they were undergoing risk-taking and risky decision-making during functional magnetic resonance imaging (fMRI). During risk-taking and as compared to HCs, IGD subjects selected more risk-disadvantageous trials and demonstrated less activation of the anterior cingulate, posterior cingulate and middle temporal gyrus. During risky decision-making and as compared to HCs, IGD subjects showed shorter response times and less activations of the inferior frontal and superior temporal gyri. Taken together, data suggest that IGD subjects show impaired executive control in selecting risk-disadvantageous choices, and they make risky decisions more hastily and with less recruitment of regions implicated in impulse control. These results suggest a possible neurobiological underpinning for why IGD subjects may exhibit poor control over their game-seeking behaviors even when encountering negative consequences and provide possible therapeutic targets for interventions in this population.

1. Introduction

Internet gaming disorder (IGD) is a public health concern and a disorder that is included in Section 3 of the DSM-5 as a condition warranting further study (American Psychiatric Association, 2013; Griffiths et al., 2014). IGD shares features with substance (Dong et al., 2015a, 2014, 2013d; Hare et al., 2014; Lin et al., 2015b) and gambling (Potenza, 2014a,b) addictions. Unlike drug addiction or substance abuse, no chemical or substance intake is involved in IGD, although excessive Internet gaming may lead to physical dependence, similar to other addictions (Dong et al., 2013a; Holden, 2001). These findings suggest that online experiences may change brain function and related cognitive processes in manners that may perpetuate Internet gaming (Dong et al., 2011; Holden, 2001; Weinstein and Lejoyeux, 2010).

Risk-taking and risky decision-making contribute importantly to the development of addictions (Balogh et al., 2013). Disadvantageous risk-taking and improper decision-making may lead to problematic behaviors such as substance abuse (Rutherford et al., 2010), pathological gambling (Potenza, 2014b), and IGD (Dong et al., 2015b). Reduced cognitive capacity or willingness to avoid excessive behavioral engagement in pleasurable activities may contribute to the development of various clinical problems, including behavioral and substance addictions (Potenza et al., 2013). Individuals with IGD may not fully consider outcomes when making decisions (Bechara et al., 2002; Dong et al., 2013b; Floros and Siomos, 2012; Pawlikowski and Brand, 2011). Individuals with IGD may display a ‘myopia for the future’ in which they tend to pursue immediately rewarding experiences (e.g., playing online) and neglect long-term adverse consequences, as has been found in drug addictions (Bechara et al., 2002; Floros and Siomos, 2012; Pawlikowski and Brand, 2011). Although studies have demonstrated disadvantageous decision-making in association with IGD (Dong et al., 2015a; Lin et al., 2015a), unanswered questions exist regarding the precise mechanisms that may lead

* Corresponding author. Department of Psychology, Zhejiang Normal University, 688 Yingbin Road, Jinhua, Zhejiang Province, 321004, PR China.
E-mail address: dongguangheng@zjnu.edu.cn (G. Dong).

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individuals to game excessively or compulsively. This study aimed to examine the neural features underlying decision-making in IGD during performance of a risk-taking and risky decision-making task.

Specific brain regions, including the inferior frontal gyrus (IFG) and orbitofrontal cortex (OFC), are involved in decision-making (Cazzell et al., 2012; Rushworth et al., 2012; Sheth et al., 2012). IFG activation may signal subjective risk and contribute to the formation of subjective feelings during decision-making (Craig, 2009). The OFC contributes importantly to value-based decision-making (Glascher et al., 2012; Kable and Glimcher, 2009). In addiction, these prefrontal cortex regions and associated brain structures have been implicated in the development and maintenance of problematic patterns of Internet use (Brand et al., 2014; Dong and Potenza, 2014). A meta-analysis suggests that dysfunction of or anatomic deficits in the frontal cortex contribute to impaired impulse control (Meng et al., 2015). Thus, in current study, we hypothesized that IGD subjects would show impaired decision-making that would relate to activations in these brain regions.

Performance of risk-taking and decision-making tasks involves evaluation of risky features and avoidance of disadvantageous choices (Rothman and Salovey, 1997). In pathological gambling and substance-use disorders, reduced activation of reward-related circuitry is observed during gambling-related decision-making (de Ruiter et al., 2012; Tanabe et al., 2007). Thus, in the current study, we hypothesized that IGD relative to healthy control subjects (HCs) would show disadvantageous decision-making that would relate to diminished activation of reward-related fronto-striatal brain regions.

During risk-taking or risky decision-making, executive inhibition contributes to better impulse control and advantageous decision-making. Some brain regions, such as the anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC), contribute importantly in this regard. The ACC has been associated with error monitoring, conflict detection and performance monitoring in decision-making (Holroyd and Coles, 2002; Platt and Huettel, 2008) and is involved in anticipating risks, especially potential losses (Krawitz et al., 2010). The posterior cingulate cortex (PCC), and DLPFC were found to be more active during choice of risky versus safe options (Paulus et al., 2003; Schonberg et al., 2011). Thus, we hypothesized that IGD versus HC subjects would show disadvantageous decision-making that would relate to activations in executive-function-related cortical brain regions.

2. Methods and materials

2.1. Participant selections

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. The methods were conducted in accordance with the approved guidelines. Participants were university students and were recruited through advertisements. Participants were right-handed males (20 IGD subjects, 16 HCs). IGD and HC groups did not significantly differ in age (IGD mean = 21.33, SD = 2.18 years; HC mean = 21.90, SD = 2.33 years; $t = 0.66$, $p = 0.48$). All subjects had normal or corrected to normal vision. Only males were included due to higher IGD prevalence in men than in women. All participants provided written informed consent and completed a structured psychiatric interviews (MINI) (Lecrubier et al., 1997) that was performed by an experienced psychiatrist lasted approximately 15 min. All participants were free of Axis I psychiatric disorders assessed in the MINI. We further assessed 'depression' with the Beck Depression Inventory (Beck et al., 1961) and only participants scoring less than 5 were included. All participants were instructed not to use any substances of abuse, including caffeinated drinks, on the day of scanning. No participants reported previous use of illicit drugs (e.g., cocaine, marijuana).

Internet gaming disorder was determined based on scores of 50 or more on Young's online Internet addiction test (IAT) (Young, 2009) and, at the same time, meeting a proposed IGD diagnosis per DSM-5 criteria (Petry et al., 2014). Young's IAT consists of 20 items assessing problematic Internet use, including psychological dependence, compulsive use, withdrawal, problems in school or work, sleep, family or time management (Young, 2009). The IAT is a valid and reliable instrument that can be used in classifying Internet addiction (Widyanto et al., 2011; Widyanto and McMurran, 2004). For each item, a graded response is selected from 1 = "Rarely" to 5 = "Always", or "Does not Apply". Scores over 50 indicate occasional or frequent internet-related problems (www.netaddiction.com). When recruiting IGD subjects, we added an additional criterion on Young's established measures of IAT, 'you spend ___% of your online time playing online games' (>80%).

2.2. Task and procedure

The fMRI task used an event-related design. This task consisted of 80 trials. Each trial was divided into three stages: Decision stage (risk-taking), gamble stage (risky decision-making), and feedback stage. Fig. 1a shows the event sequence of each trial during the task. First, a white cross was presented at the center of a black screen for 500 ms to cue the beginning of a new trial. During the subsequent risk-taking stage, participants were asked to select one from of two risky options (see details on decision stage in Fig. 1b). This selection process lasted for 4000 ms at most and disappeared once the participant made a selection. After a variable period of delay (mean 3000 ms, ranging from 1000 to 5000 ms), the risky decision-making stage followed (Fig. 1c). During this stage, participants would see 4 backs of cards and were asked to guess which one was red and indicate their response by a button press within 2000 ms (the order of the cards during the gamble stage was randomized). If they missed, they would lose 15 Chinese Yuan (about $2.5 USD). After the response and a delay ranging from 1000 to 3000 ms (mean = 2000 ms), the selected card would turn over and show participants the outcome, which was presented for a period of 1000 ms. Participants won/lost the amount according to the card color and the number on the card. The next trial begun after a jittered delay (mean 3000 ms, ranged from 2000 to 4500 ms). Subjects were asked to make responses with their right hands. The experiment was presented using E-prime software (Psychology Software Tools, Inc.).

2.3. Risk-taking

During the risk-taking stage, two lines of cards (each line consisting of 4 cards) were presented on the computer screen (see Fig. 1b), with the red cards and the amount on it suggesting winning some amount, and the yellow ones suggesting losing some amount. The cards were shown in colors to indicate the results (red, win; yellow, lose), win/lose rates (the proportions of different color cards), and win/lose amount (the number on cards).

The probability and magnitude of the gains/losses were manipulated to create advantageous/disadvantageous risky selections. The advantageous risk-taking means the sum of numbers on red cards (win) are larger than those on yellow cards (loss) (risk-advantageous). It suggests that although participants have opportunities to lose a big amount, they are more likely to win money in the long run. In Fig. 1b, the first line is risk-advantageous selection ($(45*0.75)+(-35*0.25) = 25$ Yuan). In contrast, the second line in