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Reduced Loss Aversion and Inhibitory Control in Adolescents With Internet Gaming Disorder

Lingxiao Wang
Institute of Psychology, Chinese Academy of Sciences, Beijing, China, and University of Chinese Academy of Sciences

Moqian Tian
Teachers College of Beijing Union University and Beijing Union University

Ya Zheng
Dalian Medical University

Qi Li and Xun Liu
Institute of Psychology, Chinese Academy of Sciences, Beijing, China, and University of Chinese Academy of Sciences

As adolescents are in a crucial developmental period, they are more susceptible than adults to Internet gaming disorder (IGD). The dual-system model proposed by Casey, Jones, and Hare (2008) emphasized the equal importance of reward-seeking and cognitive control systems in accounting for adolescents' risky behaviors. Considering that no study has simultaneously examined reward seeking (loss aversion, i.e., loss sensitivity relative to gain sensitivity) and cognitive control (inhibitory control) in IGD, this study aimed to investigate loss aversion and inhibitory control in the same IGD adolescent population. Forty five adolescent patients with IGD and 43 matched healthy control participants completed a mixed gambles task and a stop-signal task to measure loss aversion and inhibitory control, respectively. Two main findings were identified in this study. First, the IGD participants showed concurrent reduced loss aversion and inhibitory control, suggesting that differences in both systems serve as behavioral markers of IGD in adolescents. Second, the IGD participants were categorized into 2 distinct subtypes based on differences in loss aversion and inhibitory control, which implies specific therapies for specific subtypes of IGD adolescents. Therefore, this study extends the application of the dual-system model to explain adolescents' excessive Internet gaming behavior.

Keywords: Internet gaming disorder, adolescents, reward seeking, inhibitory control, subtypes of IGD

Internet gaming disorder (IGD), which is characterized by uncontrollable and recurrent gaming behavior despite multiple negative consequences (American Psychiatric Association [APA], 2013), has rapidly grown into a global health problem. IGD is associated with social deficits, poor occupational/academic performance, and family relationship problems (Gentile et al., 2017; Kaptsis, King, Delfabbro, & Gradisar, 2016; Sugaya, Shirasaka, Takahashi, & Kanda, 2019). IGD is also reported to have high comorbidity with psychiatric disorders such as anxiety, depression, and attention deficit hyperactivity disorders (Mehroof & Griffiths, 2010; Mentzoni et al., 2011). Considering the acute health effects of IGD and its prevalence, the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*) committee included it in Section 3 as a tentative disorder warranting further evidence and proposed diagnostic criteria for IGD based on those for gambling disorder (GD; APA, 2013; Petry et al., 2014).

As they are in a particular immature developmental period characterized by rapid alterations in psychological, physical, and social development, adolescents are more susceptible than adults to various addictive disorders, including IGD (Crews, He, & Hodge, 2007; Gansner et al., 2019; Tsai, 2018). Most epidemiologic studies reported that IGD was more prevalent among adolescent gamers than adult gamers (Festl, Scharkow, & Quandt, 2013; Mentzoni et al., 2011; Rehbein, Kleimann, & Mössle, 2010; Xin et al., 2018), and adolescents with IGD suffered more severe repercussions than adults (Griffiths, Davies, & Chappell, 2004; Lemmens, Valkenburg, & Peter, 2011; Mentzoni et al., 2011; Young, 2009). Moreover, studies on substance use disorder (SUD) and GD found that many substance users and gamblers had their first experience with substance use or gambling in adolescence

Lingxiao Wang, CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China, and Department of Psychology, University of Chinese Academy of Sciences; Moqian Tian, Department of Psychology, Teachers College of Beijing Union University, and Learning and Psychological development institution for Children and Adolescents, Beijing Union University; Ya Zheng, Department of Psychology, Dalian Medical University; Qi Li and Xun Liu, CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, and Department of Psychology, University of Chinese Academy of Sciences.

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Correspondence concerning this article should be addressed to Qi Li, CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, 16 Lincui Road, Chaoyang District, Beijing 100101, China. E-mail: liqi@psych.ac.cn

(Andersen & Teicher, 2009; Yip et al., 2011) and that the intensity of substance use (i.e., alcohol use) and gambling in adolescence correlated with the severity of substance use and gambling problems in adulthood (Burge, Pietrzak, Molina, & Petry, 2004; McCambridge, McAlaney, & Rowe, 2011). Thus, investigating the behavioral traits of adolescents with IGD may provide a better understanding of IGD's etiology and promote the early treatment and prevention of IGD.

Based on numerous animal and human studies, Casey, Jones, and Hare (2008) proposed a dual-system neurobiological model to explain the increased vulnerability for risk-taking behaviors (e.g., substance abuse and gambling) in adolescents. This model suggests that the high incidence of adolescents' risky behaviors may be the result of distinct developmental patterns of reward seeking and cognitive control observed during adolescence—that is, heightened reward seeking in adolescents relative to children and adults and lack of cognitive control relative to adults (Steinberg, 2010). In line with this dual-system model, other models likewise stress the equal importance of reward-seeking and cognitive control systems in accounting for adolescent risky behaviors including substance abuse and problematic gambling (Casey, Jones, & Hare, 2008; Ernst, Pine, & Hardin, 2006; Somerville & Casey, 2010; Steinberg, 2007). Therefore, simultaneously examining the characteristics of reward-seeking and cognitive control functions in adolescents with IGD could verify the dual-system model.

First, some studies have revealed enhanced reward seeking in adolescents with IGD. Questionnaire studies have reported that adolescents who display a high level of reward seeking are at a high risk of developing IGD (Park et al., 2013), and the severity of online gaming addiction has been positively related to sensation seeking in adolescents (Hu, Zhen, Yu, Zhang, & Zhang, 2017). One behavioral study using the simple gambling task has found that adolescents with IGD relative to those without IGD made more risky decisions in search of higher rewards, indicating enhanced reward-seeking behavior in IGD (Li et al., 2019). Similar to adolescents with IGD, adults with IGD made more risky and disadvantageous choices than healthy controls (HC) to obtain high rewards during several reward-related decision-making tasks, including the simple gambling task (He et al., 2017), the cups task (Yao, Chen, et al., 2015), and the game of dice task (Pawlikowski & Brand, 2011; Yao et al., 2014). Additionally, adults with IGD displayed increased brain activity in reward-related regions—that is, the orbitofrontal cortex and the ventral striatum—when presented with positive rewards in the card guessing task and the cups task (Dong, Huang, & Du, 2011; Liu et al., 2017). These findings consistently indicated enhanced reward seeking in individuals with IGD, which resembled that in individuals with SUD and GD (Bava & Tapert, 2010; Bjork, Smith, & Hommer, 2008; Crews et al., 2007; Fauth-Bühler, Mann, & Potenza, 2017; Leiserson & Pihl, 2007).

However, most of the mentioned IGD studies have primarily focused on the processing of positive rewards (gains), and few studies have investigated the appraisal of negative rewards (losses) in IGD, particularly the trade-off between gains and losses when making decisions. Identifying the appraisal of losses and sensitivity to losses relative to gains in addiction populations is essential for understanding why addicted individuals show reduced aversion to the negative outcomes of addictive behavior, which is one of the core features of substance and behavioral addiction disorders (including SUD, IGD, and GD; Genauck et al., 2017; Petry et al., 2014). Accordingly, loss aversion, a phenomenon in which individuals are more sensitive to potential losses than to potential gains of the same magnitude when presented with a risky decision (Kahneman & Tversky, 1979)—that is, loss sensitivity relative to gain sensitivity—might be affected in addicted populations. There have been studies reporting reduced loss aversion in subjects with SUD and GD compared to that in HC (Fridberg et al., 2010; Genauck et al., 2017; Lorains et al., 2014; Vassileva et al., 2013). However, the status of loss aversion in adolescents with IGD remains unknown.

Second, some studies have sought to examine cognitive control in adolescents with IGD; however, they have not drawn consistent conclusions. Cognitive control encompasses a set of cognitive processes that govern goal-directed action and adaptive responses to complex, novel, or ambiguous situations, including response activation and inhibition, performance monitoring, and working memory (Cools & D'Esposito, 2011). Several IGD studies have utilized the Stroop or go/no-go task to study cognitive control performance (particularly response inhibition) in adolescents with IGD. Using the color-word Stroop task, some researchers have found worse inhibitory control in IGD indicated by significantly more errors committed by adolescents with IGD than HC during incongruent conditions (Cai et al., 2016; Xing et al., 2014; Yuan et al., 2016), whereas other researchers have found the same inhibitory control ability between adolescents with IGD and HC in the go/no-go task (Ding et al., 2014). Although one neuroimaging study has found abnormal structural changes within cognitive control-related regions such as the dorsolateral prefrontal cortex and anterior cingulate cortex in adolescents with IGD (H. Wang et al., 2015), it remains ambiguous whether inhibitory control is insufficient in adolescents with IGD.

Analogously, studies applying the color-word Stroop, go/no-go, or stop-signal task in adults with IGD have also provided mixed results. Several studies recruiting IGD participants from hospitals or medical centers have reported significant intergroup differences between IGD and matched HC (J. Choi et al., 2013; S. Choi et al., 2014; Kim et al., 2017; Zhou, Yuan, Yao, Li, & Cheng, 2010), whereas others recruiting IGD participants from colleges or the general public have reported no significant group difference (Chen et al., 2015; Irvine et al., 2013; Jeromin, Rief, & Barke, 2016; Ko et al., 2014). In addition to the diverse experimental settings (Chen et al., 2015; Jeromin et al., 2016; Zhou et al., 2010), the addiction severity of the IGD subjects involved in these studies might be the major plausible explanation for these inconsistent results. The IGD participants in most of the studies reporting significantly worse inhibition of IGD were patients in hospitals or medical centers seeking treatment due to serious negative consequences from excessive Internet gaming. However, those IGD groups recruited from colleges or the general public in several studies had similar inhibitory control ability on the behavioral level as HC. Testing whether patients with severe symptoms of IGD have worse inhibitory control may help resolve these conflicting findings.

To our knowledge, this is the first study to simultaneously investigate reward seeking (loss aversion) and cognitive control (response execution and particularly response inhibition) in the same adolescent population, aiming to provide targets for the effective treatment and prevention of IGD. In the present study, first, regarding reward seeking, we utilized the mixed gambles task (Tom, Fox, Trepel, & Poldrack, 2007) to identify loss aversion in adolescents with IGD. In general, people accept a gamble when the amount they could gain is at least twice the amount they could lose, indicating individuals' loss aversion when making decisions (Kahneman & Tversky, 1979; Tom et al., 2007). However, individuals with SUD and GD exhibit reduced loss aversion than HC (Fridberg et al., 2010; Genauck et al., 2017). Thus, we assumed that compared to HC, adolescents with IGD would show reduced loss aversion in the form of enhanced risk taking with loss as individuals with SUD and GD do. Second, the stop-signal task (Band, van der Molen, & Logan, 2003) was applied to examine response execution and particularly response inhibition in adolescents with IGD. The horse race model suggested by Logan (1994) effectively describes the behavior in this task of withholding a response already underway, which assumes that go (execution) and stop (inhibition) processes run independently and that both determine the processes for winning the race. Considering the high addiction severity of the IGD participants that we recruited from the addiction medicine center and the decreased behavioral inhibition in individuals with SUD and GD in this task (S. Choi et al., 2014; Smith, Mattick, Jamadar, & Iredale, 2014), we assumed that adolescents with IGD would exhibit worse response execution and inhibition ability than HC.

Additionally, to explore the risk factors of adolescents with IGD from a more comprehensive perspective, we employed an exploratory analysis (cluster analysis) to identify different subtypes of adolescents with IGD in terms of differences in risk taking with loss and inhibitory control. According to the previous studies on IGD reviewed earlier, individuals with IGD seem to generally show elevated levels of reward seeking; however, the inhibitory control of individuals with IGD appear to be related to their addiction severity; that is, reduced inhibitory control has been found in patients with severe clinical symptoms but not in individuals with mild addiction severity. Accordingly, in the present study, first, we assumed that adolescents with IGD would concurrently exhibit enhanced risk taking with loss and reduced inhibitory control ability. Second, we assumed that adolescents with IGD would be divided into distinct subtypes according to the severity of IGD. Adolescents with mild IGD would mainly exhibit enhanced risk taking with loss, whereas adolescents with serious IGD would concurrently exhibit enhanced risk taking with loss and reduced inhibitory control.

Method

Participants and Procedure

Forty-five right-handed adolescents with IGD were recruited from a local addiction medicine center. The following inclusion criteria for the IGD group were used: (a) answered "yes" to at least five questions on the eight-item Young's Diagnostic Questionnaire for Internet Addiction (YDQ; Young, 1998), which has been demonstrated to be reliable in identifying Internet addiction (Li, Nan, et al., 2016; Li, Tian, et al., 2016; M. Tian et al., 2018); (b) met the diagnostic criteria for IGD proposed by the *DSM–5* committee (Petry et al., 2014), as determined by an experienced psychiatrist; (c) spent most of their Internet time engaged in online gaming; (d) spent more than 3 hr engaged in online gaming daily for a minimum of 2 years; and (e) experienced serious impairments in family relations, academics, or other social functions due to long-term online gaming and needed effective treatments, as reported by their parents and doctors at the hospital. Forty-three right-handed matched HC were recruited from a local high school. The inclusion criteria for the HC group were as follows: (a) scored less than 4 on the YDQ, (b) failed to meet the *DSM–5* criteria for IGD, and (c) played online games for less than 1 hr per day. The exclusion criteria for all the participants were (a) head trauma or injury history; (b) previous or current depression or anxiety disorders according to the Beck Depression Inventory-II (BDI-II > 13; Beck, Steer, Ball, & Ranieri, 1996; Z. Wang et al., 2011) and the Beck Anxiety Inventory (BAI > 15; Beck, Epstein, Brown, & Steer, 1988); and (c) current or historical records of neurological/psychiatric disorders (including schizophrenia and substance dependence), as determined through the structured psychiatric interviews (Lecrubier et al., 1997) conducted by an experienced psychiatrist.

The demographic information of the two groups is shown in Table 1. There was no group difference in terms of age, gender, education level, or years of Internet use; however, the IGD group spent significantly more time online and playing online games and scored higher on the YDQ than the HC group. All participants and their parents provided written informed consent in conformity with the Declaration of Helsinki before the study. Then, all participants completed the mixed gambles task and the stop-signal task (the order of the tasks was balanced across participants) as well as several questionnaires. All participants were given approximately 150 yuan as compensation for their participation after finishing all the experiments. This study was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences.

Materials

Mixed gambles task. A version of the mixed gambles task was administered to study loss aversion in adolescents with IGD (Tom et al., 2007). To familiarize the participants with the task, they were asked to complete a training block with six trials before the formal block began. Each participant was provided with an initial endowment of 50 yuan. In this task, all participants were told that any decision in this task would be honored with real money, and an initial endowment of 50 yuan was given to convince them to engage in this task as real gambling. Figure 1A shows the timeline of one sample trial in the task. A mixed gamble entailing equal probabilities (50%) of gaining one amount of money or losing another amount was presented to the participants for up to 6,000 ms. Possible gains varied from 10 yuan to 40 yuan in two increments, and possible losses varied from 5 yuan to 20 yuan in one increment (Figure 1B). Therefore, there were 256 possible combinations of gains and losses, which were presented randomly across four blocks of 64 trials each. The participants needed to make a decision indicating acceptance or rejection of the gamble presented. To motivate the participants to consider the subjective attractiveness of each gamble, they were asked to press one of four keys to indicate the degree to which they accepted or rejected each gamble ("F" = strongly accept, "G" = weakly accept, "H" = weakly reject, and "J" = strongly reject). After a key press, the chosen key was highlighted by a red outline for 1,000 ms. The outcome of each gamble was decided randomly

Table 1
Demographic and Behavioral Characteristics of the Two Groups

Demographic/Behavioral characteristic	IGD (*N* = 45)	HC (*N* = 43)	*t* or χ^2	*p*
Age (years)	15.58 ± 1.14	15.72 ± .96	−0.64	.526
Gender (M/F)	33/12	32/11	−0.01	.908
Education (years)	9.62 ± 1.27	9.70 ± .99	−0.31	.757
Years of Internet use	5.53 ± 2.29	5.20 ± 2.59	0.65	.521
Total online time per day (hours)	5.92 ± 3.42	1.22 ± 1.91	8.00	<.001
Online gaming per day (hours)	4.69 ± 3.57	0.83 ± 1.64	6.57	<.001
YDQ	6.02 ± .89	2.26 ± 1.05	18.18	<.001
BIS-11 total	48.13 ± 12.77	32.15 ± 11.52	6.15	<.001
BIS-11 attention	53.56 ± 18.43	37.21 ± 13.21	4.80	<.001
BIS-11 motor	47.94 ± 17.31	33.20 ± 17.30	4.00	<.001
BIS-11 nonplanning	42.89 ± 15.68	26.05 ± 12.04	5.63	<.001
BIS/BAS-BAS total	42.49 ± 4.62	42.67 ± 4.61	−0.19	.851
BIS/BAS drive	13.53 ± 2.06	13.37 ± 1.71	0.40	.691
BIS/BAS fun seeking	12.20 ± 1.73	11.37 ± 1.94	2.12	.037
BIS/BAS reward responsiveness	16.76 ± 2.36	17.93 ± 2.11	−2.46	.016
BIS/BAS-BIS	17.78 ± 2.98	21.23 ± 2.83	−5.57	<.001
SSS total	20.20 ± 5.48	16.33 ± 5.49	3.31	.001
SSS boredom susceptibility	3.62 ± 1.64	3.51 ± 1.67	0.31	.755
SSS disinhibition	4.44 ± 2.59	2.74 ± 2.00	3.46	.001
SSS experience seeking	4.87 ± 1.97	4.07 ± 1.64	2.06	.043
SSS thrill and adventure seeking	7.27 ± 2.36	6.00 ± 2.80	2.30	.024
Self-control scores	117.04 ± 17.36	124.58 ± 17.99	−2.00	.049

Note. Table values: *M* ± *SD*. IGD = adolescents with Internet gaming disorder; HC = healthy control; YDQ = Young Diagnostic Questionnaire for Internet addiction; BIS-11 = Barratt Impulsiveness Scale-11; BIS/BAS = Behavioral Inhibition System/Behavioral Activation System; SSS = Sensation Seeking Scale.

(50/50), and the resulting amount of money was added to or subtracted from the total rewards in the program. Then, the next trial began after a blank screen was presented for 1,000 ms. Due to the positive expected value of these gambles, no participant lost money. All the participants finished this task with a net gain ranging from 54 yuan to 74 yuan.

Stop-signal task. A version of the stop-signal task based on that of Li, Nan, et al. (2016) was applied to study cognitive control in adolescents with IGD. The task was comprised of one letter discrimination block with 50 trials to estimate the deadline time for the formal testing, one training block with 16 trials (the same as those used in the formal testing), and four formal testing blocks with 256 trials. During the letter discrimination block, a fixation point was first presented for 100 ms, followed by a letter ("A" or "B") in a green box for 1,200 ms. The participants were instructed to press the keys corresponding to the letters as soon as possible using their index fingers. Half of the participants in each group (the IGD and HC groups) pressed the "F" key for "A" and the "J" key for "B," and the other half used the opposite pairing. Then, the trial ended with a black screen presented for 1,400 ms.

The training and formal testing blocks consisted of go trials and stop trials (see Figure 2). In the go trials, the participants continued to respond to the letters as they had in the previous letter discrimination block. In the stop trials, which occurred randomly in 25% of all trials, a stop signal (the green box outside the letter turned red) appeared at a variable stop signal delay (SSD) after a letter

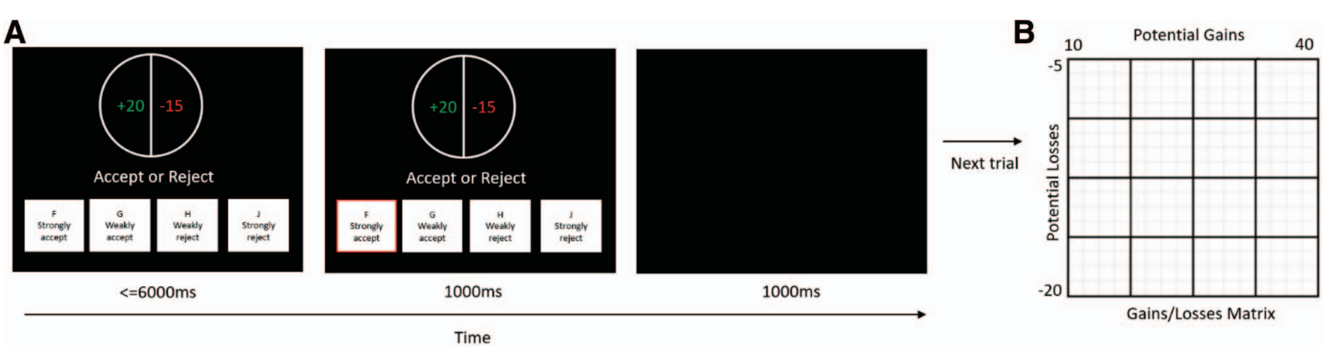

Figure 1. The mixed gambles task. Panel A: The timeline of one trial in the mixed gambles task. The participants were asked to press one of four keys to indicate the degree to which they accepted or rejected each gamble ("F" = strongly accept, "G" = weakly accept, "H" = weakly reject, and "J" = strongly reject). Panel B: All combinations of possible gains and losses in the mixed gambles task. See the online article for the color version of this figure.

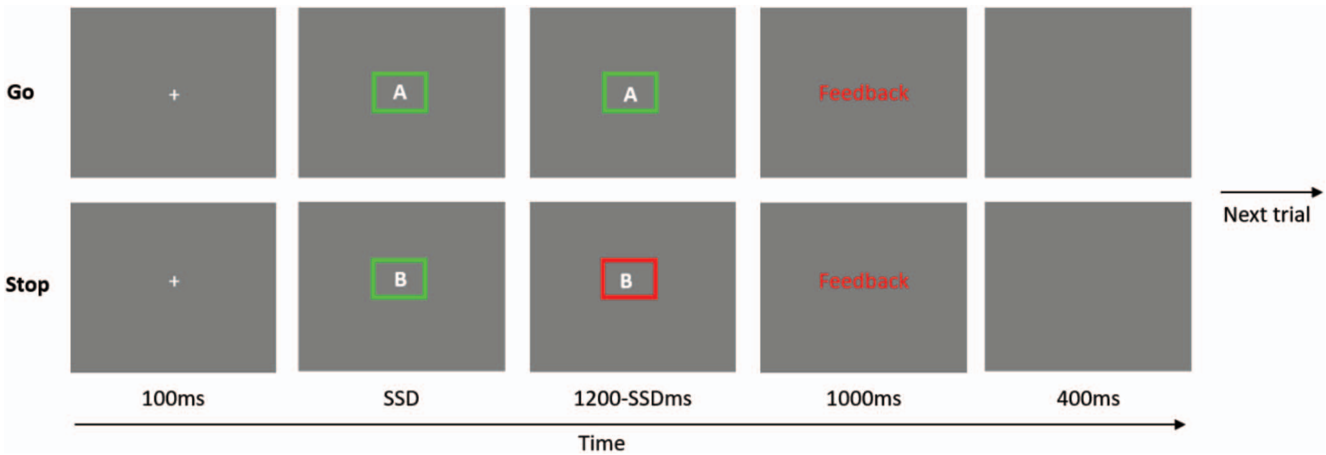

Figure 2. The timeline of one go and one stop trial in the stop-signal task. The participants were asked to respond to the letter as quickly and accurately as possible in one go trial and to withhold their response to the letter when a stop signal (the green [light grey] box outside the letter turned red [dark grey]) appeared at a variable stop signal delay (SSD) in one stop trial. See the online article for the color version of this figure.

was displayed. The participants were asked to attempt to withhold their response to the letter when they saw the stop signal. The SSD was 300 ms at the beginning of the training and testing blocks and was adapted to the participants' performance according to a staircase procedure: it was increased by 50 ms to a maximum of 500 ms in the next stop trial after a successful stop trial and decreased by 50 ms to a minimum of 0 ms after a failed stop trial, thereby yielding a success rate of inhibition of approximately 50% (Levitt, 1971). Additionally, feedback (slow, right, or wrong) was presented for 1,000 ms after the letter disappeared. "Slow" was presented when the participants did not respond to the letters in the go trials or responded correctly but their RTs were longer than their deadline values, which were calculated as the 90th percentile of each participant's reaction time (RT) to the letters in the letter discrimination block. This setting ("slow") guaranteed that the participants would not improve their accuracy by reducing their response speed. "Right" was presented when the participants responded correctly and quickly (RT < deadline value) to the letters in the go trials or withheld their response successfully in the stop trials. "Wrong" was presented when the participants responded incorrectly to the letters in the go trials or withheld their response unsuccessfully in the stop trials. Then, each trial ended with a blank screen presented for 400 ms.

Questionnaires. At the end of the experiment, all participants were asked to complete the Barratt Impulsiveness Scale-11 (BIS-11; Patton, Stanford, & Barratt, 1995; Yang et al., 2007), the Behavioral Inhibition System/Behavioral Activation System questionnaire (BIS/BAS; Carver & White, 1994; X. Tian, Xiang, & Wang, 2017), the Sensation Seeking Scale (SSS; W. Wang et al., 2000; Zuckerman, Eysenck, & Eysenck, 1978), and the Self-Control Questionnaire (SCQ; Tangney, Baumeister, & Boone, 2004). The BIS-11 has been widely utilized to assess individual impulsiveness on a 5-point scale (1 = *never*, 5 = *always*). It contains 30 items that are divided into three impulsiveness subscales: motor, nonplanning, and attentional/cognitive. The total score of impulsiveness is the mean of the three subscales. Higher scores indicate greater impulsiveness. The BIS/BAS is a 24-item questionnaire measuring two motivational systems, the aversive system and the appetitive system, on a 4-point Likert scale (1 = *totally agree*, 4 = *totally disagree*). It includes two primary scales: the BIS (seven items) and the BAS (13 items). The BAS scale is divided into three subscales: fun seeking (four items); drive (four items); and reward responsiveness (five items). Lower BIS scores indicate less sensitivity to punishment, and higher BAS scores indicate a stronger desire for reward. The SSS measures the sensation-seeking trait of participants, assessing the tendency to take risks for novel, varied, intense, and complex stimulation. It includes the subscales (10 items each) of experience seeking, thrill and adventure seeking, boredom susceptibility, and disinhibition. Higher SSS scores indicate a stronger impulse to seek sensation. The SCQ includes 36 items measuring self-control ability on a 4-point scale (1 = *never*, 4 = *always*). Higher SCQ scores are related to a broad range of positive outcomes such as better grades, better interpersonal relationships, and better emotional profiles.

Data Analysis

Mixed gambles task. Three indexes were included in the mixed gambles task: the degree of willingness to accept gambles and the acceptance rate of gambles to estimate the participants' tendency to take risky gambles, and loss aversion (λ) to estimate the participants' loss sensitivity relative to their gain sensitivity. First, the degree of willingness to accept gambles of each participant was indicated by numbers; that is, 2 indicates strongly accept, 1 indicates weakly accept, −1 indicates weakly reject, and −2 indicates strongly reject. Then, the acceptance rate was computed after the strong/weak responses of each participant were converted into accept and reject categories ("F" and "G" to accept, "H" and "J" to reject). Next, a logistic regression was performed to compute the regression coefficients for the gains (β_{gains}) and losses (β_{losses}) variables (Tom et al., 2007). The participants' decisions (accept or reject gambles) were entered as the dependent variable, and the sizes of the possible gains and losses were entered as the independent variables. The formula $\lambda = \beta_{losses}/\beta_{gains}$ was used to compute the loss aversion of each participant. A smaller λ value represents lower loss aversion. Finally, the degree of willingness to accept gambles, the acceptance rate, and the λ of the IGD and HC groups were compared with an independent sample *t* test.

Stop-signal task. The indexes for the stop-signal task included the mean go RT and error rates for all the go trials to estimate the response execution, the stop signal RT (SSRT), and the critical SSD to estimate the response inhibition of the participants. First, the mean go RT was calculated after two steps: (a) go trials where the participants did not respond to the letters (RT = 0) or responded incorrectly were removed from the data, and (b) correct go trials where the RT exceeded the criteria ($M - 3^{*}SD < \text{RT} < M + 3^{*}SD$) were marked as outliers and removed. Second, the critical SSD was calculated according to the staircase procedure used in the current version of the stop-signal task (described under the Stop-Signal Task subsection of the Materials section; Levitt, 1971). Then, the SSRT was calculated by subtracting the critical SSD from the mean RT of the go trials according to the horse race model, which assumes that the stop and go processes compete with each other in a race to the finish line (Logan, 1994). A shorter SSRT indicates better response inhibition. To identify the group differences for all the indexes, an independent sample *t* test was performed.

Correlation analyses and logistic regression. First, to identify the relationship between the participants' severity of IGD and their behavioral performance—that is, loss aversion and inhibitory control—Pearson correlation analyses of YDQ scores and the log(λ), log(SSRT) of all the participants were performed, respectively. Especially considering that the variances of λ and SSRT are unequal in the IGD and HC groups, the λ and SSRT of all participants were log-transformed before performing correlation analyses, which eliminated the heteroscedasticity of variance in λ and SSRT (Field, 2013). Second, to provide further evidence for the relationship among IGD, loss aversion, and inhibitory control, a logistic regression predicting IGD was performed using SPSS statistical software (Version 22.0). To determine the model with the best fit to the current data, an initial hierarchical analysis was conducted to hierarchically build the models of interest—that is, Model 1, which includes only the λ values as the predicted variable; Model 2, which includes the λ and SSRT values as the predicted variables; and Model 3, which includes the λ and SSRT values and the interaction between λ and SSRT as the predicted variables. Whether or not the participants have IGD was entered as the dependent variable in the three models. The results showed that Model 2 fit the data best. Additionally, the results of testing the assumptions on the linearity of the logit and multicollinearity in logistic regression showed the collinearity between λ and the interaction term (λ × SSRT), which may bias the model effect. Accordingly, Model 2 was further analyzed to determine the effects of the λ and SSRT values on IGD.

Cluster analyses. For exploratory analysis of the relationship between loss aversion and inhibitory control in the IGD group, we conducted a cluster analysis to classify the behavioral indices (λ and SSRT). Two-step cluster analysis was selected because it can automatically determine the optimal number of clusters without specifying the number of clusters in advance (Kayri, 2007; Yu & Chan, 2012). The two-step cluster analysis on λ and SSRT was analyzed based on the Akaike information criterion (AIC) and the highest log-likelihood distance measures (ratio of distance measures). Further, to evaluate the relationship of the severity of IGD, loss aversion, and inhibitory control in the IGD group, we added the YDQ scores, λ, and SSRT of the IGD group as the clustering variables in the two-step cluster analysis with the same settings. All the cluster analyses were conducted using SPSS statistical software.

Results

Questionnaires

As shown in Table 1, the IGD group had significantly higher scores on the BIS-11 scale, including its three subscales, and significantly lower scores on the SCQ than the HC group, indicating more impulsivity and weaker self-control ability in the IGD group. Moreover, compared to the HC group, the IGD group had significantly higher SSS total scores and higher scores on the subscales, except on the SSS boredom susceptibility. The IGD group also had higher BIS/BAS fun seeking scores and lower BIS/BAS reward responsiveness and BIS/BAS-BIS scores.

Mixed Gambles Task

First, the IGD group exhibited a significantly higher degree of willingness to accept gambles (IGD: 1.03 ± 0.51, HC: 0.36 ± 0.75, $t(72) = 4.91$, $p < .001$; also see Figure 3B) and higher acceptance rates of gambles (IGD: 79.23 ± 12.65%, HC: 61.43 ± 20.96%, $t(66) = 4.75$, $p < .001$; see Figure 3A and 4A) than the HC group, which consistently revealed a higher tendency to take risky gambles in the IGD group relative to the HC group. Second, in accordance with previous research (Tom et al., 2007), the HC group was slower and more hesitant to decide whether to accept gambles when the possible gain was twice the amount of the possible loss, which can be seen in Figure 3C and the loss aversion λ of the HC group (HC: 1.76 ± 0.86). However, this feature was not observed in the IGD group. The IGD group exhibited shorter decision times relative to the HC group when possible gains were twice the amount of potential losses (Figure 3C). Additionally, the loss aversion λ of the IGD group was significantly smaller than that of the HC group (IGD: 1.28 ± 0.58, $t(72) = -3.09$, $p = .003$; Figure 4A).

Stop-Signal Task

The success rates of inhibition in stop trials were 51.98% for the IGD group and 50.69% for the HC group, indicating that the present task was performed successfully. Although the two groups had similar critical SSDs (IGD: 290 ± 88 ms, HC: 265 ± 68 ms, $t[86] = 1.51$, $p = .134$), compared to the HC group, the IGD group showed both slower go RT (IGD: 529 ± 97 ms, HC: 479 ± 73 ms, $t[86] = 2.69$, $p = .009$) and SSRT (IGD: 239 ± 47 ms, HC: 214 ± 29 ms, $t[75] = 2.95$, $p = .005$). Moreover, the IGD group made marginally more errors in the go trials than the HC group (IGD: 6.04 ± 8.95%, HC: 3.44 ± 2.62%, $t[52] = 1.86$, $p = .069$; Figure 4B).

Correlation Analyses and Logistic Regression

First, for the relationship between the severity of IGD and behavioral performance, we found that the YDQ scores were significantly correlated with log(λ), $r = -.248$, $p = .021$, and log(SSRT), $r = .278$, $p = .009$, indicating that higher YDQ scores were associated with lower loss aversion and worse response inhibition. Second, for

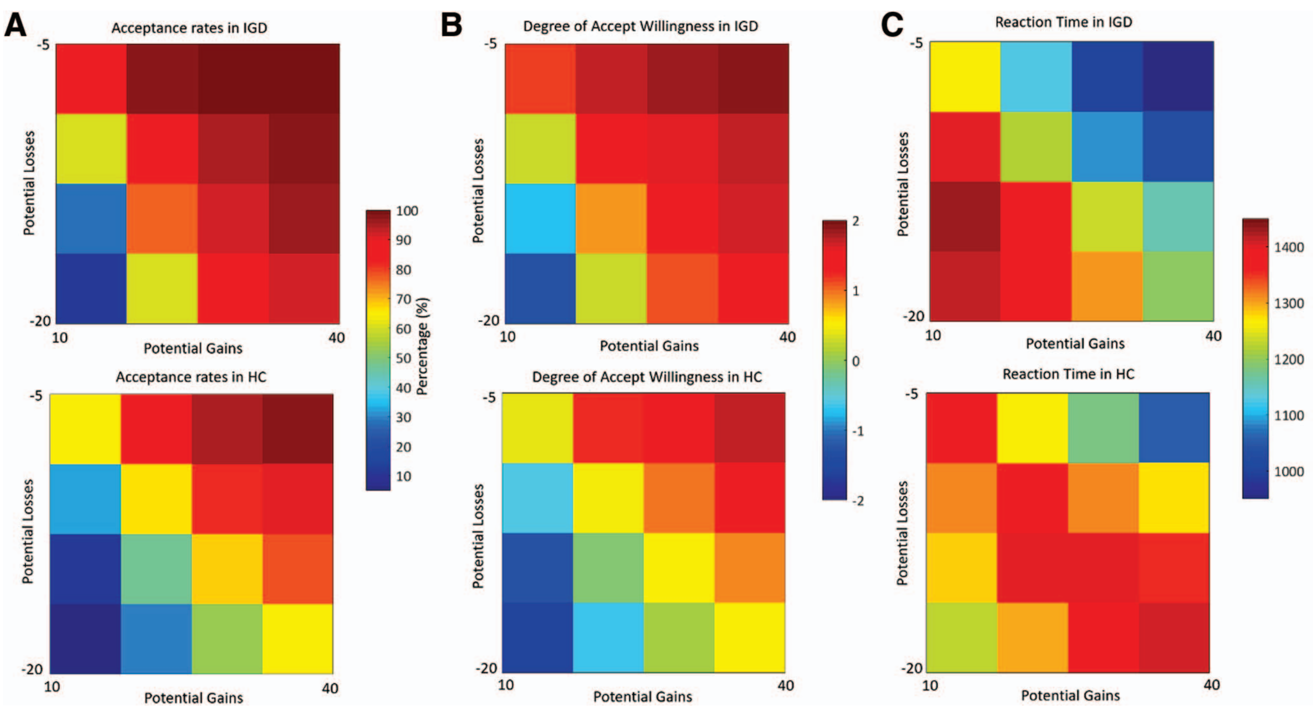

Figure 3. The color-coded heatmaps of the mixed gambles task. Panel A: Color-coded heatmaps of acceptance rates in the IGD and HC groups. Red (dark grey in the upper right corner) indicates higher acceptance rates of gambles, and blue (dark grey in the bottom left corner) indicates lower acceptance rates. Panel B: Color-coded heatmaps of degree of willingness to accept gambles in the IGD and HC groups. Red (dark grey in the upper right corner) indicates stronger willingness, and blue (dark grey in the bottom left corner) indicates weaker willingness to accept gambles. Panels A and B consistently showed that compared to HC, the IGD group had a stronger tendency to accept gambles even when potential gains ≤ 2 × potential losses (values on and below the diagonal). Panel C: Color-coded heatmaps of RT in the IGD and HC groups. Red (dark grey in the bottom left corner of RT in IGD) indicates longer decision times, and blue (dark grey in the upper right corner) indicates shorter decision times. The HC group exhibited the longest decision times when potential gains = 2 × potential losses (values on the diagonal), whereas this feature was not observed in the IGD group. IGD = Internet gaming disorder; HC = healthy control. See the online article for the color version of this figure.

the logistic regression predicting IGD, the results showed that lower λ values significantly predicted a high risk of having IGD (β = −1.11, odds ratio = 0.33, p = .011); that is, an increase in the λ value would reduce the odds of having IGD. Higher SSRT values significantly predicted a high risk of having IGD (β = 0.02, odds ratio = 1.02, p = .024); that is, an increase in the SSRT value would increase the odds of having IGD. The obtained logistic model was statistically significant ($\chi^2 = 16.94$, $p < .001$). The overall percentage of prediction was 69%.

Cluster Analyses

First, for the cluster analysis of λ and SSRT in the IGD group, the results showed that the IGD participants were divided into three types (cluster quality = 0.7, AIC = 45.35; Figure 5A). Most of the IGD group (71.1%) was classified as Cluster 2; that is, they had small λ values and a short SSRT similar to that of the HC participants. Cluster 1 showed that 20% of the IGD group had the smallest λ values and longest SSRT. In addition, a very small number of IGD participants (8.9%) showed relatively large λ values and short SSRT (Cluster 3), which were similar to those of the HC participants. Second, for the cluster analysis of YDQ scores, λ, and SSRT in the IGD group, the results showed that the IGD participants were divided into two types (cluster quality = 0.5, AIC = 89.83; Figure 5B). Cluster 1 showed that the IGD participants with higher YDQ scores had smaller λ values and longer SSRT, whereas the IGD participants in Cluster 2 with lower YDQ scores had larger λ values (but still smaller than those of the HC participants) and a shorter SSRT comparable to that of HC participants.

Discussion

To the best of our knowledge, this is the first study to simultaneously investigate reward seeking (loss aversion) and cognitive control (inhibitory control) in the same IGD adolescent population. The present study found that the IGD group concurrently displayed greater risk taking with loss (reduced loss aversion) when making decisions and worse response execution and inhibitory control than the HC group. Additionally, the IGD group reported a stronger desire for sensation seeking and less sensitivity to punishment and weaker self-control ability than the HC group. These results suggest that enhanced risk taking with loss and reduced inhibitory control ability may be crucial risk factors in the high incidence of IGD in adolescents and, thus, support the dual-system model of adolescents (Casey,

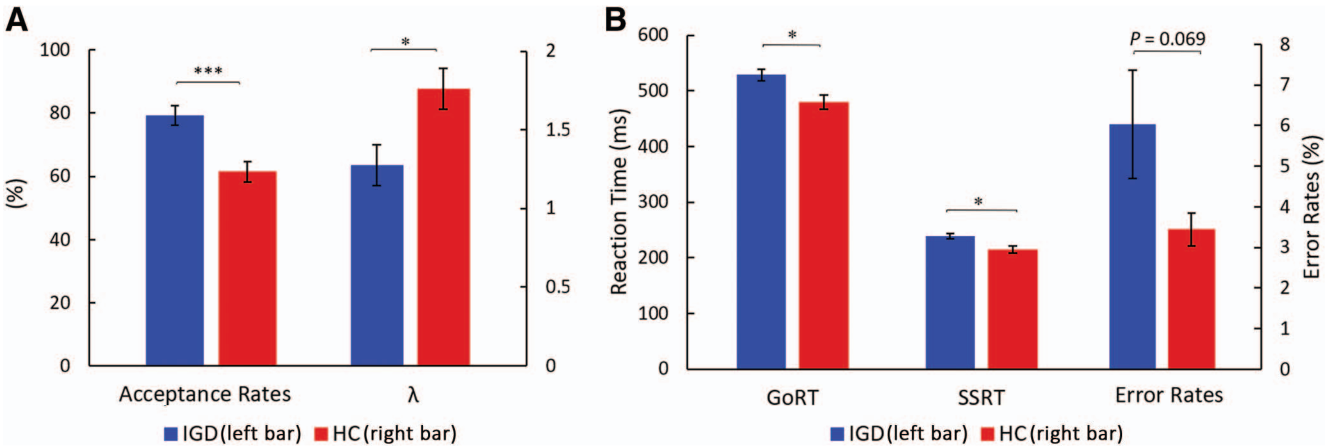

Figure 4. The results of the mixed gambles task and the stop-signal task. Panel A: The IGD (left bar) group showed higher acceptance rates of gambles and lower loss aversion (λ, the ratio of gains/losses in gambles) than the HC (right bar) group. Panel B: The IGD (left bar) group showed longer GoRT and SSRT and more errors in the go trials than the HC (right bar) group. GoRT and SSRT are reported in ms (left *y*-axis), and GoError rates are reported in percentages (right *y*-axis). $^{*}p < .05$. $^{***}p < .005$. IGD = Internet gaming disorder; HC = healthy control; GoRT = RT in correct go trials; SSRT = stop signal RT; GoError rates = error rates in go trials. See the online article for the color version of this figure.

Jones, & Hare, 2008) from the perspective of adolescents with IGD. However, we found that some of the participants with relatively mild IGD showed greater risk taking with loss and intact inhibitory control similar to that of the HC participants, while the remainder of the participants with serious IGD showed differences in both facets relative to HC. This result may imply that compared with inhibitory control, greater risk taking with loss is more likely to be the initial risk factor of IGD in adolescents. As the addiction severity increases, the inhibitory control of adolescents with IGD is also reduced. This finding further enriches the dual-system model of adolescents from the perspective of the importance of the two systems in adolescents' risk for IGD.

Enhanced Risk Taking With Loss and Reduced Inhibitory Control in Adolescents With IGD

The present study revealed that compared to their HC peers, adolescents with IGD had enhanced risk taking with loss and

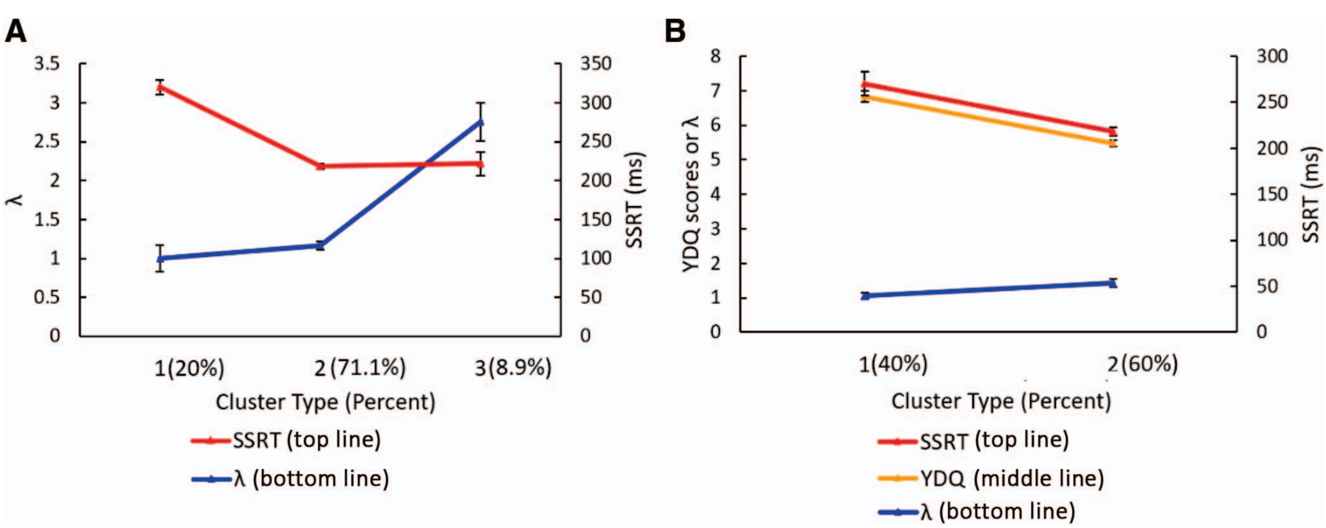

Figure 5. The results of the cluster analyses. Panel A: Cluster types of λ (bottom line) and SSRT (top line) in the IGD (Internet gaming disorder) group. λ(bottom line) is on the left *y*-axis, and SSRT (top line) is on the right *y*-axis. Panel B: Cluster types of YDQ (middle line) scores, λ (bottom line), and SSRT (top line) in the IGD group. The YDQ (middle line) scores and λ (bottom line) are on the left *y*-axis, and the SSRT (top line) is on the right *y*-axis. YDQ = Young's Diagnostic Questionnaire for Internet Addiction; SSRT = stop signal RT; percent = the percentage of IGD participants in each cluster type. See the online article for the color version of this figure.

reduced inhibitory control ability. First, adolescents with IGD exhibited enhanced risk taking with loss (reduced loss aversion) relative to HC. By employing the mixed gambles task, we found that compared to HC, adolescents with IGD exhibited a higher tendency to accept gambles and took less time to make risky decisions, suggesting a tendency in adolescents with IGD to take risks in search of high rewards. This may be viewed as a replication of the studies that have reported individuals with IGD's elevated risk-seeking levels (L. Wang et al., 2016; Yao et al., 2017; Yao, Chen, et al., 2015). More importantly, the IGD group showed smaller λ values than the HC group. Generally, people require to be offered a potential gain that is at least double the amount of the potential loss before deciding to gamble, as indicated by $\lambda \approx 2$ in the HC group, which indicates loss aversion when making decisions. However, the adolescents with IGD showed reduced loss aversion, as indicated by the mean $\lambda = 1.28$ of the IGD group. This reduction in loss aversion is in accordance with the findings in adults with problematic Internet use (Li, Nan, et al., 2016) and other addiction disorders (SUD and GD; Giorgetta et al., 2014; Genauck et al., 2017). Furthermore, in addition to the current questionnaire results showing that there is stronger sensation seeking and less punishment sensitivity in the IGD group than in the HC group, evidence from fMRI research has demonstrated enhanced gain sensitivity and decreased loss sensitivity in adults with IGD when performing reward-based decision-making tasks (Dong, Hu, & Lin, 2013; Dong et al., 2011). Therefore, the present results of the mixed gambles task suggest that although adolescents with IGD similarly attach more importance to potential losses than potential gains in making risky decisions, compared with HC, they display reduced aversion to loss, which underlies the core trait of IGD, specifically, underestimating future severe negative outcomes due to excessive Internet gaming.

Second, compared with HC, the adolescents with IGD exhibited reduced inhibitory control. In the stop-signal task, which is widely used to quantitatively measure individuals' response execution and inhibitory control abilities, the IGD group took longer to execute responses to go stimuli and made marginally more errors and required more time to inhibit responses when presented with stop signals than the HC group. As the horse race model suggests, the speed of go responses and the speed of stop responses are independent; hence, a longer go RT and higher error rates in the go condition are indications of worse response execution, and a longer SSRT is an indication of worse inhibitory control (Lijffijt, Kenemans, Verbaten, & van Engeland, 2005). The meaning of a longer SSRT is not altered by the go RT pattern. The present results demonstrate worse response execution and inhibitory control in the adolescent patients with severe IGD, which is consistent with the results of studies recruiting IGD patients with severe clinical symptoms (S. Choi et al., 2014; Kim et al., 2017; Zhou et al., 2010) and individuals with SUD and GD (Fauth-Bühler et al., 2017; Smith et al., 2014). In combination with the questionnaire results showing that there is greater impulsivity and weaker self-control ability in the IGD group than in the HC group, the present findings largely confirm our hypothesis that patients with severe symptoms of IGD will have reduced inhibitory control. In addition, the result that higher YDQ scores are associated with worse response inhibition also supports this hypothesis. Overall, our findings demonstrate that individuals with severe IGD have decreased inhibition of addictive behaviors (excessive Internet gaming) and, thus, need effective treatment and help to get rid of serious negative consequences due to IGD. In contrast, many problematic Internet gaming users who do not seek treatment might recover naturally, showing similar self-control ability as that of a healthy population (Chen et al., 2015; Jeromin et al., 2016; Ko et al., 2014).

Additionally, the result of the logistic regression revealed that greater risk taking with loss and worse inhibitory control could significantly predict the high risk of having IGD. This finding to some degree coincides with the dual-system model of adolescents described earlier: adolescents who have stronger reward seeking and lack cognitive control tend to engage more in risky behaviors (Casey, Jones, & Hare, 2008). Our findings provide evidence of this model from a behavioral perspective and, thus, extend the application of the model to explain adolescents' excessive Internet gaming behavior. When faced with the daily decision to play or not play games, in contrast to adolescents with regular gaming or nongaming habits, the pleasure of playing games is more dominant in adolescents with IGD than the various negative consequences of IGD regarding factors such as academic performance, social relationships, and sleep quality. Meanwhile, they are also insufficient in inhibiting their gaming behavior once it has been initiated. These findings from adolescents with IGD are similar to those found for individuals with SUD who exhibit an exaggerated reward system and insufficient inhibitory control system (Casey, Getz, & Galvan, 2008; Casey & Jones, 2010; Geier, 2013; Xie et al., 2014). Although the previous studies have also identified these differences in the two systems in adults with IGD by employing other reward-based decision-making tasks and inhibitory control tasks (Dong, Li, Wang, & Potenza, 2017; Dong, Lin, Hu, Xie, & Du, 2015; Yao, Wang, et al., 2015), the present study extends these results to adolescents with IGD.

Subtypes of Adolescents With IGD and Implications for Treatment

There are several subtypes of adolescents with IGD classified based on differences in reward-seeking and inhibitory control systems. When using cluster analyses to probe the differences in these two systems in adolescents with IGD more carefully, we first found that the IGD group could be categorized into three types: except for a few IGD participants who showed normal risk taking with loss and good inhibitory control ability similar to those of the HC participants, most IGD participants showed only enhanced risk taking with loss, and their inhibitory control was unabated. A small number of IGD participants concurrently showed enhanced risk taking with loss and reduced inhibitory control. Although the IGD group showed differences in both reward seeking and inhibitory control overall, different IGD participants showed different patterns regarding the two systems.

Second, after adding the addiction severity of IGD to the cluster analysis, we found that the IGD group could be categorized into two types: 40% of the IGD participants reported a higher severity of IGD and concurrently showed greater risk taking with loss and worse inhibitory control than those of the HC participants, and 60% of the IGD participants reported a low severity of IGD and showed greater risk taking with loss than that of the HC participants but intact inhibitory control similar to that of the HC participants. This result may imply that compared with HC, adolescents with severe IGD are different in both their reward-seeking and inhibitory control systems, whereas adolescents with relatively mild IGD are mainly different in their reward-seeking systems. Consistent with our hypotheses, to a certain degree, the present cluster analysis results are in accord with the previous findings on IGD's reward-seeking and inhibitory control systems reviewed in the introduction section and help resolve the previous conflicting findings; that is, individuals with IGD consistently showed enhanced reward seeking (e.g., Dong et al., 2011; He et al., 2017). However, the results regarding their inhibitory control system showed inconsistencies; the patients with severe clinical symptoms exhibited worse inhibitory control (e.g., J. Choi et al., 2013; Zhou et al., 2010), whereas individuals with mild addiction severity of IGD did not (e.g., Chen et al., 2015; Irvine et al., 2013). Accordingly, the present results may imply that compared to inhibitory control, greater risk taking with loss is more likely to serve as an initial and developmental risk factor of IGD in adolescents. However, the inhibitory control of adolescents with IGD is also reduced when the addiction severity of IGD is high.

Overall, the present study adopted a more comprehensive perspective to investigate the risk factors of adolescents with IGD with respect to the reward-seeking and inhibitory control systems and, thus, deepened our understanding of the dual-system model of adolescents. This finding implies that in future studies, it may be more effective to choose different therapies for different subtypes of adolescents with IGD than to neglect the differences among these subtypes and to regard all such adolescents as belonging to a single type. For example, for adolescents with IGD who exhibit less severe clinical symptoms, first-line therapy may target their reward seeking. In addition, effective treatments for adolescents who have severe clinical symptoms should aim to train and strengthen patients' reward seeking and inhibitory control ability at the same time. Notably, reward seeking can be revised by insight and incentive (Knutson, Westdorp, Kaiser, & Hommer, 2000), whereas inhibitory control is largely an involuntary process (van Gaal, Lamme, Fahrenfort, & Ridderinkhof, 2010; van Gaal, Ridderinkhof, van den Wildenberg, & Lamme, 2009), which might suggest that compared with reward seeking, individual inhibitory control is relatively hard to modify. This may imply that seeking effective treatments to improve inhibitory control is crucial for patients with severe IGD symptoms to break free from IGD in future studies.

Limitations

Four limitations should be noted. First, given that this is a cross-sectional study, we cannot conclude whether the differences in the two systems are causes or effects of IGD. However, as the early studies have indicated, some adolescents who have exaggerated reward seeking and insufficient inhibitory control will be more prone than their peers to engage in risky behaviors (Casey & Jones, 2010; Casey, Jones, & Hare, 2008). Thus, paying particular attention to adolescents with stronger reward seeking and worse inhibitory control than their peers is necessary for effective prevention and intervention of IGD at an earlier stage. Second, although the sample size of 45 IGD participants in the current cluster analyses met the requirement (no less than 5^*2^K cases [K = number of variables]; Formann, 1984), the current sample size is small for cluster analysis, which might limit the power of the study's conclusions. We expect larger sample sizes in future studies to verify the current results of cluster analyses. Third, considering the possibility that the absence of a social component (e.g., other players or observers) in the mixed gambles task leading to a weak incentive to avoid loss in the IGD group, we suggest the following as one way to address this issue in future studies: creating a social situation with several players/observers simultaneously performing the mixed gambles task to maximize the participants' motivation. Meanwhile, the control group could be replaced by regular game players without IGD. In fact, many game players spend almost the same amount of time playing online games as players with IGD but do not develop IGD (L. Wang et al., 2017). Therefore, comparing players with IGD and regular players without IGD in a task with a social situation might further verify the reduced loss aversion in IGD. Fourth, it should be noted that although the dual-system model could properly explain the nonlinear shifts in adolescents distinct from children and adults (i.e., heightened reward seeking in adolescents relative to children and adults and lack of cognitive control relative to adults), it is necessary to be aware that dual-system models are not infallible (Keren & Schul, 2009). As Keren and Schul commented, the conceptual clarity and empirical evidence employed to support dual-system models have not been rigorous enough and have been insufficient to propose a dual system. The dual-system model used in the current study should be understood more objectively and dialectically.

Conclusion

The present study simultaneously examined the reward-seeking and cognitive control systems in adolescents with IGD for the first time and revealed differences in both systems—that is, enhanced risk taking with loss and reduced inhibitory control in adolescents with IGD. This finding is consistent with the findings in adults with IGD, which may suggest that differences in both systems serve as behavioral markers of IGD. Moreover, the results of cluster analyses might provide insight into specific subtypes of adolescents with IGD regarding the differences in the two systems from a more comprehensive perspective, emphasizing the importance of specific therapies for specific subtypes of adolescents with IGD. However, the present study merely measured one facet of reward seeking and cognitive control by applying the mixed gambles task and stop-signal task, respectively. Additionally, this study did not integrate the two systems in one task to examine the interplay between reward-seeking and cognitive control systems in adolescents with IGD. It is essential to investigate the other facets of reward seeking and cognitive control and integrate the methods associated with both systems in future studies to gain greater insights into the mechanisms underlying IGD and to develop effective prevention and treatment.

References

Andersen, S. L., & Teicher, M. H. (2009). Desperately driven and no brakes: Developmental stress exposure and subsequent risk for substance abuse. *Neuroscience and Biobehavioral Reviews, 33,* 516–524. http://dx.doi.org/10.1016/j.neubiorev.2008.09.009

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Band, G. P., van der Molen, M. W., & Logan, G. D. (2003). Horse-race model simulations of the stop-signal procedure. *Acta Psychologica, 112,* 105–142. http://dx.doi.org/10.1016/S0001-6918(02)00079-3

Bava, S., & Tapert, S. F. (2010). Adolescent brain development and the risk for alcohol and other drug problems. *Neuropsychology Review, 20,* 398–413. http://dx.doi.org/10.1007/s11065-010-9146-6

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56,* 893–897. http://dx.doi.org/10.1037/0022-006X.56.6.893

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. (1996). Comparison of Beck Depression Inventories -IA and -II in psychiatric outpatients. *Journal of Personality Assessment, 67,* 588–597. http://dx.doi.org/10.1207/s15327752jpa6703_13

Bjork, J. M., Smith, A. R., & Hommer, D. W. (2008). Striatal sensitivity to reward deliveries and omissions in substance dependent patients. *NeuroImage, 42,* 1609–1621. http://dx.doi.org/10.1016/j.neuroimage.2008.06.035

Burge, A. N., Pietrzak, R. H., Molina, C. A., & Petry, N. M. (2004). Age of gambling initiation and severity of gambling and health problems among older adult problem gamblers. *Psychiatric Services, 55,* 1437–1439. http://dx.doi.org/10.1176/appi.ps.55.12.1437

Cai, C., Yuan, K., Yin, J., Feng, D., Bi, Y., Li, Y., . . . Tian, J. (2016). Striatum morphometry is associated with cognitive control deficits and symptom severity in internet gaming disorder. *Brain Imaging and Behavior, 10,* 12–20. http://dx.doi.org/10.1007/s11682-015-9358-8

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology, 67,* 319–333. http://dx.doi.org/10.1037/0022-3514.67.2.319

Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review, 28,* 62–77. http://dx.doi.org/10.1016/j.dr.2007.08.003

Casey, B. J., & Jones, R. M. (2010). Neurobiology of the adolescent brain and behavior: Implications for substance use disorders. *Journal of the American Academy of Child & Adolescent Psychiatry, 49,* 1189–1201. http://dx.doi.org/10.1097/00004583-201012000-00005

Casey, B. J., Jones, R. M., & Hare, T. A. (2008). The adolescent brain. *Annals of the New York Academy of Sciences, 1124,* 111–126. http://dx.doi.org/10.1196/annals.1440.010

Chen, C. Y., Huang, M. F., Yen, J. Y., Chen, C. S., Liu, G. C., Yen, C. F., & Ko, C. H. (2015). Brain correlates of response inhibition in Internet gaming disorder. *Psychiatry and Clinical Neurosciences, 69,* 201–209. http://dx.doi.org/10.1111/pcn.12224

Choi, J. S., Park, S. M., Lee, J., Hwang, J. Y., Jung, H. Y., Choi, S. W., . . . Lee, J. Y. (2013). Resting-state beta and gamma activity in Internet addiction. *International Journal of Psychophysiology, 89,* 328–333. http://dx.doi.org/10.1016/j.ijpsycho.2013.06.007

Choi, S. W., Kim, H. S., Kim, G. Y., Jeon, Y., Park, S. M., Lee, J. Y., . . . Kim, D. J. (2014). Similarities and differences among Internet gaming disorder, gambling disorder and alcohol use disorder: A focus on impulsivity and compulsivity. *Journal of Behavioral Addictions, 3,* 246–253. http://dx.doi.org/10.1556/JBA.3.2014.4.6

Cools, R., & D'Esposito, M. (2011). Inverted-U-shaped dopamine actions on human working memory and cognitive control. *Biological Psychiatry, 69,* e113–e125. http://dx.doi.org/10.1016/j.biopsych.2011.03.028

Crews, F., He, J., & Hodge, C. (2007). Adolescent cortical development: A critical period of vulnerability for addiction. *Pharmacology, Biochemistry and Behavior, 86,* 189–199. http://dx.doi.org/10.1016/j.pbb.2006.12.001

Ding, W. N., Sun, J. H., Sun, Y. W., Chen, X., Zhou, Y., Zhuang, Z. G., . . . Du, Y. S. (2014). Trait impulsivity and impaired prefrontal impulse inhibition function in adolescents with internet gaming addiction revealed by a Go/No-Go fMRI study. *Behavioral and Brain Functions, 10,* 20. http://dx.doi.org/10.1186/1744-9081-10-20

Dong, G., Hu, Y., & Lin, X. (2013). Reward/punishment sensitivities among internet addicts: Implications for their addictive behaviors. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 46,* 139–145. http://dx.doi.org/10.1016/j.pnpbp.2013.07.007

Dong, G., Huang, J., & Du, X. (2011). Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: An fMRI study during a guessing task. *Journal of Psychiatric Research, 45,* 1525–1529. http://dx.doi.org/10.1016/j.jpsychires.2011.06.017

Dong, G., Li, H., Wang, L., & Potenza, M. N. (2017). Cognitive control and reward/loss processing in Internet gaming disorder: Results from a comparison with recreational Internet game-users. *European Psychiatry, 44,* 30–38. http://dx.doi.org/10.1016/j.eurpsy.2017.03.004

Dong, G., Lin, X., Hu, Y., Xie, C., & Du, X. (2015). Imbalanced functional link between executive control network and reward network explain the online-game seeking behaviors in Internet gaming disorder. *Scientific Reports, 5,* 9197. http://dx.doi.org/10.1038/srep09197

Ernst, M., Pine, D. S., & Hardin, M. (2006). Triadic model of the neurobiology of motivated behavior in adolescence. *Psychological Medicine, 36,* 299–312. http://dx.doi.org/10.1017/S0033291705005891

Fauth-Bühler, M., Mann, K., & Potenza, M. N. (2017). Pathological gambling: A review of the neurobiological evidence relevant for its classification as an addictive disorder. *Addiction Biology, 22,* 885–897. http://dx.doi.org/10.1111/adb.12378

Festl, R., Scharkow, M., & Quandt, T. (2013). Problematic computer game use among adolescents, younger and older adults. *Addiction, 108,* 592–599. http://dx.doi.org/10.1111/add.12016

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. London, UK: SAGE Publication.

Formann, A. K. (1984). *Die latent-class-analyse: Einführung in die Theorie und Anwendung*. Weinheim, Germany: Beltz.

Fridberg, D. J., Queller, S., Ahn, W.-Y., Kim, W., Bishara, A. J., Busemeyer, J. R., . . . Stout, J. C. (2010). Cognitive mechanisms underlying risky decision-making in chronic cannabis users. *Journal of Mathematical Psychology, 54,* 28–38. http://dx.doi.org/10.1016/j.jmp.2009.10.002

Gansner, M., Belfort, E., Cook, B., Leahy, C., Colon-Perez, A., Mirda, D., & Carson, N. (2019). Problematic Internet use and associated high-risk behavior in an adolescent clinical sample: Results from a survey of psychiatrically hospitalized youth. *Cyberpsychology, Behavior, and Social Networking, 22,* 349–354. http://dx.doi.org/10.1089/cyber.2018.0329

Geier, C. F. (2013). Adolescent cognitive control and reward processing: Implications for risk taking and substance use. *Hormones and Behavior, 64,* 333–342. http://dx.doi.org/10.1016/j.yhbeh.2013.02.008

Genauck, A., Quester, S., Wüstenberg, T., Mörsen, C., Heinz, A., & Romanczuk-Seiferth, N. (2017). Reduced loss aversion in pathological gambling and alcohol dependence is associated with differential alterations in amygdala and prefrontal functioning. *Scientific Reports, 7,* 16306. http://dx.doi.org/10.1038/s41598-017-16433-y

Gentile, D. A., Bailey, K., Bavelier, D., Brockmyer, J. F., Cash, H., Coyne, S. M., . . . Young, K. (2017). Internet gaming disorder in children and adolescents. *Pediatrics, 140,* S81–S85. http://dx.doi.org/10.1542/peds.2016-1758H

Giorgetta, C., Grecucci, A., Rattin, A., Guerreschi, C., Sanfey, A. G., & Bonini, N. (2014). To play or not to play: A personal dilemma in pathological gambling. *Psychiatry Research, 219,* 562–569. http://dx.doi.org/10.1016/j.psychres.2014.06.042

Griffiths, M. D., Davies, M. N. O., & Chappell, D. (2004). Online computer gaming: A comparison of adolescent and adult gamers. *Journal of Adolescence, 27,* 87–96. http://dx.doi.org/10.1016/j.adolescence.2003.10.007

He, W., Qi, A., Wang, Q., Wu, H., Zhang, Z., Gu, R., & Luo, W. (2017). Abnormal reward and punishment sensitivity associated with Internet addicts. *Computers in Human Behavior, 75,* 678–683. http://dx.doi.org/10.1016/j.chb.2017.06.017

Hu, J., Zhen, S., Yu, C., Zhang, Q., & Zhang, W. (2017). Sensation seeking and online gaming addiction in adolescents: A moderated mediation model of positive affective associations and impulsivity. *Frontiers in Psychology, 8,* 699. http://dx.doi.org/10.3389/fpsyg.2017.00699

Irvine, M. A., Worbe, Y., Bolton, S., Harrison, N. A., Bullmore, E. T., & Voon, V. (2013). Impaired decisional impulsivity in pathological videogamers. *PLOS ONE, 8,* e75914. http://dx.doi.org/10.1371/journal.pone.0075914

Jeromin, F., Rief, W., & Barke, A. (2016). Using two web-based addiction Stroops to measure the attentional bias in adults with Internet gaming disorder. *Journal of Behavioral Addictions, 5,* 666–673. http://dx.doi.org/10.1556/2006.5.2016.075

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica, 47,* 263–292. http://dx.doi.org/10.2307/1914185

Kaptsis, D., King, D. L., Delfabbro, P. H., & Gradisar, M. (2016). Withdrawal symptoms in internet gaming disorder: A systematic review. *Clinical Psychology Review, 43,* 58–66. http://dx.doi.org/10.1016/j.cpr.2015.11.006

Kayri, M. (2007). Two-step clustering analysis in researches: A case study. *Eurasian Journal of Educational Research, 28,* 89–99. Retrieved from https://www.researchgate.net/publication/290434553_Two-step_Cluster_Analysis_in_Researches_A_Case_Study

Keren, G., & Schul, Y. (2009). Two is not always better than one: A critical evaluation of two-system theories. *Perspectives on Psychological Science, 4,* 533–550. http://dx.doi.org/10.1111/j.1745-6924.2009.01164.x

Kim, Y. J., Lim, J. A., Lee, J. Y., Oh, S., Kim, S. N., Kim, D. J., . . . Choi, J. S. (2017). Impulsivity and compulsivity in Internet gaming disorder: A comparison with obsessive-compulsive disorder and alcohol use disorder. *Journal of Behavioral Addictions, 6,* 545–553. http://dx.doi.org/10.1556/2006.6.2017.069

Knutson, B., Westdorp, A., Kaiser, E., & Hommer, D. (2000). FMRI visualization of brain activity during a monetary incentive delay task. *NeuroImage, 12,* 20–27. http://dx.doi.org/10.1006/nimg.2000.0593

Ko, C. H., Hsieh, T. J., Chen, C. Y., Yen, C. F., Chen, C. S., Yen, J. Y., . . . Liu, G. C. (2014). Altered brain activation during response inhibition and error processing in subjects with Internet gaming disorder: A functional magnetic imaging study. *European Archives of Psychiatry and Clinical Neuroscience, 264,* 661–672. http://dx.doi.org/10.1007/s00406-013-0483-3

Lecrubier, Y., Sheehan, D. V., Weiller, E., Amorim, P., Bonora, I., Harnett Sheehan, K., . . . Dunbar, G. C. (1997). The Mini International Neuropsychiatric Interview (MINI): A short diagnostic structured interview: Reliability and validity according to the CIDI. *European Psychiatry, 12,* 224–231. http://dx.doi.org/10.1016/S0924-9338(97)83296-8

Leiserson, V., & Pihl, R. O. (2007). Reward-sensitivity, inhibition of reward-seeking, and dorsolateral prefrontal working memory function in problem gamblers not in treatment. *Journal of Gambling Studies, 23,* 435–455. http://dx.doi.org/10.1007/s10899-007-9065-5

Lemmens, J. S., Valkenburg, P. M., & Peter, J. (2011). The effects of pathological gaming on aggressive behavior. *Journal of Youth and Adolescence, 40,* 38–47. http://dx.doi.org/10.1007/s10964-010-9558-x

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *Journal of the Acoustical Society of America, 49,* 467–477. http://dx.doi.org/10.1121/1.1912375

Li, Q., Nan, W., Taxer, J., Dai, W., Zheng, Y., & Liu, X. (2016). Problematic internet users show impaired inhibitory control and risk taking with losses: Evidence from stop signal and mixed gambles tasks. *Frontiers in Psychology, 7,* 370. http://dx.doi.org/10.3389/fpsyg.2016.00370

Li, Q., Tian, M., Taxer, J., Zheng, Y., Wu, H., Sun, S., & Liu, X. (2016). Problematic Internet users' discounting behaviors reflect an inability to delay gratification, not risk taking. *Cyberpsychology, Behavior, and Social Networking, 19,* 172–178. http://dx.doi.org/10.1089/cyber.2015.0295

Li, Q., Wang, Y., Yang, Z., Dai, W., Zheng, Y., Sun, Y., & Liu, X. (2019). Dysfunctional cognitive control and reward processing in adolescents with Internet gaming disorder. *Psychophysiology*. Advance online publication. http://dx.doi.org/10.1111/psyp.13469

Lijffijt, M., Kenemans, J. L., Verbaten, M. N., & van Engeland, H. (2005). A meta-analytic review of stopping performance in attention-deficit/hyperactivity disorder: Deficient inhibitory motor control? *Journal of Abnormal Psychology, 114,* 216–222. http://dx.doi.org/10.1037/0021-843X.114.2.216

Liu, L., Xue, G., Potenza, M. N., Zhang, J. T., Yao, Y. W., Xia, C. C., . . . Fang, X. Y. (2017). Dissociable neural processes during risky decision-making in individuals with Internet-gaming disorder. *NeuroImage Clinical, 14,* 741–749. http://dx.doi.org/10.1016/j.nicl.2017.03.010

Logan, G. D. (1994). On the ability to inhibit thought and action: A users' guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention memory & language* (pp. 189–239). Cambridge, MA: Academic Press.

Lorains, F. K., Dowling, N. A., Enticott, P. G., Bradshaw, J. L., Trueblood, J. S., & Stout, J. C. (2014). Strategic and non-strategic problem gamblers differ on decision-making under risk and ambiguity. *Addiction, 109,* 1128–1137. http://dx.doi.org/10.1111/add.12494

McCambridge, J., McAlaney, J., & Rowe, R. (2011). Adult consequences of late adolescent alcohol consumption: A systematic review of cohort studies. *PLOS Medicine, 8,* e1000413. http://dx.doi.org/10.1371/journal.pmed.1000413

Mehroof, M., & Griffiths, M. D. (2010). Online gaming addiction: The role of sensation seeking, self-control, neuroticism, aggression, state anxiety, and trait anxiety. *Cyberpsychology, Behavior, and Social Networking, 13,* 313–316. http://dx.doi.org/10.1089/cyber.2009.0229

Mentzoni, R. A., Brunborg, G. S., Molde, H., Myrseth, H., Skouverøe, K. J., Hetland, J., & Pallesen, S. (2011). Problematic video game use: Estimated prevalence and associations with mental and physical health. *Cyberpsychology, Behavior, and Social Networking, 14,* 591–596. http://dx.doi.org/10.1089/cyber.2010.0260

Park, S. M., Park, Y. A., Lee, H. W., Jung, H. Y., Lee, J. Y., & Choi, J. S. (2013). The effects of behavioral inhibition/approach system as predictors of Internet addiction in adolescents. *Personality and Individual Differences, 54,* 7–11. http://dx.doi.org/10.1016/j.paid.2012.07.033

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology, 51,* 768–774. http://dx.doi.org/10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Pawlikowski, M., & Brand, M. (2011). Excessive Internet gaming and decision making: Do excessive World of Warcraft players have problems in decision making under risky conditions? *Psychiatry Research, 188,* 428–433. http://dx.doi.org/10.1016/j.psychres.2011.05.017

Petry, N. M., Rehbein, F., Gentile, D. A., Lemmens, J. S., Rumpf, H. J., Mößle, T., . . . O'Brien, C. P. (2014). An international consensus for assessing internet gaming disorder using the new *DSM–5* approach. *Addiction, 109,* 1399–1406. http://dx.doi.org/10.1111/add.12457

Rehbein, F., Kleimann, M., & Mössle, T. (2010). Prevalence and risk factors of video game dependency in adolescence: Results of a German nationwide survey. *Cyberpsychology, Behavior, and Social Networking, 13,* 269–277. http://dx.doi.org/10.1089/cyber.2009.0227

Smith, J. L., Mattick, R. P., Jamadar, S. D., & Iredale, J. M. (2014). Deficits in behavioural inhibition in substance abuse and addiction: A meta-analysis. *Drug and Alcohol Dependence, 145,* 1–33. http://dx.doi.org/10.1016/j.drugalcdep.2014.08.009

Somerville, L. H., & Casey, B. J. (2010). Developmental neurobiology of cognitive control and motivational systems. *Current Opinion in Neurobiology, 20,* 236–241. http://dx.doi.org/10.1016/j.conb.2010.01.006

Steinberg, L. (2007). Risk taking in adolescence: New perspectives from brain and behavioral science. *Current Directions in Psychological Science, 16,* 55–59. http://dx.doi.org/10.1111/j.1467-8721.2007.00475.x

Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental Psychobiology, 52,* 216–224. http://dx.doi.org/10.1002/dev.20445

Sugaya, N., Shirasaka, T., Takahashi, K., & Kanda, H. (2019). Biopsychosocial factors of children and adolescents with internet gaming disorder: A systematic review. *BioPsychoSocial Medicine, 13,* 3. http://dx.doi.org/10.1186/s13030-019-0144-5

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality, 72,* 271–324. http://dx.doi.org/10.1111/j.0022-3506.2004.00263.x

Tian, M., Tao, R., Zheng, Y., Zhang, H., Yang, G., Li, Q., & Liu, X. (2018). Internet gaming disorder in adolescents is linked to delay discounting but not probability discounting. *Computers in Human Behavior, 80,* 59–66. http://dx.doi.org/10.1016/j.chb.2017.10.018

Tian, X., Xiang, H., & Wang, Y. (2017). Reliability and validity of the Chinese version of the BIS-BAS Scale. *Journal of Guizhou Medical University, 42,* 59–63. http://dx.doi.org/10.19367/j.cnki.1000-2707.2017.04.011

Tom, S. M., Fox, C. R., Trepel, C., & Poldrack, R. A. (2007). The neural basis of loss aversion in decision-making under risk. *Science, 315,* 515–518. http://dx.doi.org/10.1126/science.1134239

Tsai, J. Y. (2018). *The Internet activities, gratifications, and health consequences related to compulsive Internet use* (Unpublished doctoral dissertation). University of Southern California. Retrieved from https://search.proquest.com/docview/2183237903?pq-origsite=gscholar

van Gaal, S., Lamme, V. A. F., Fahrenfort, J. J., & Ridderinkhof, K. R. (2010). Dissociable brain mechanisms underlying the conscious and unconscious control of behavior. *Journal of Cognitive Neuroscience, 23,* 91–105. http://dx.doi.org/10.1162/jocn.2010.21431

van Gaal, S., Ridderinkhof, K. R., van den Wildenberg, W. P. M., & Lamme, V. A. F. (2009). Dissociating consciousness from inhibitory control: Evidence for unconsciously triggered response inhibition in the stop-signal task. *Journal of Experimental Psychology: Human Perception and Performance, 35,* 1129–1139. http://dx.doi.org/10.1037/a0013551

Vassileva, J., Ahn, W.-Y., Weber, K. M., Busemeyer, J. R., Stout, J. C., Gonzalez, R., & Cohen, M. H. (2013). Computational modeling reveals distinct effects of HIV and history of drug use on decision-making processes in women. *PLOS ONE, 8,* e68962. http://dx.doi.org/10.1371/journal.pone.0068962

Wang, H., Jin, C., Yuan, K., Shakir, T. M., Mao, C., Niu, X., . . . Zhang, M. (2015). The alteration of gray matter volume and cognitive control in adolescents with internet gaming disorder. *Frontiers in Behavioral Neuroscience, 9,* 64. http://dx.doi.org/10.3389/fnbeh.2015.00064

Wang, L., Wu, L., Lin, X., Zhang, Y., Zhou, H., Du, X., & Dong, G. (2016). Dysfunctional default mode network and executive control network in people with Internet gaming disorder: Independent component analysis under a probability discounting task. *European Psychiatry, 34,* 36–42. http://dx.doi.org/10.1016/j.eurpsy.2016.01.2424

Wang, L., Wu, L., Wang, Y., Li, H., Liu, X., Du, X., & Dong, G. (2017). Altered brain activities associated with craving and cue reactivity in people with Internet gaming disorder: Evidence from the comparison with recreational internet game users. *Frontiers in Psychology, 8,* 1–12. http://dx.doi.org/10.3389/fpsyg.2017.01150

Wang, W., Wu, Y. X., Peng, Z. G., Lu, S. W., Yu, L., Wang, G. P., . . . Wang, Y. H. (2000). Test of sensation seeking in a Chinese sample. *Personality and Individual Differences, 28,* 169–179. http://dx.doi.org/10.1016/S0191-8869(99)00092-6

Wang, Z., Yuan, C. M., Huang, J., Ze-Zhi, L. I., Chen, J., Zhang, H. Y., & Fang, Y. R. (2011). Reliability and validity of the Chinese version of Beck Depression Inventory-II among depression patients. *Chinese Mental Health Journal, 25,* 476–480. http://dx.doi.org/10.3969/j.issn.1000-6729.2011.06.014

Xie, C., Shao, Y., Ma, L., Zhai, T., Ye, E., Fu, L., . . . Li, S. J. (2014). Imbalanced functional link between valuation networks in abstinent heroin-dependent subjects. *Molecular Psychiatry, 19,* 10–12. http://dx.doi.org/10.1038/mp.2012.169

Xin, M., Xing, J., Pengfei, W., Houru, L., Mengcheng, W., & Hong, Z. (2018). Online activities, prevalence of Internet addiction and risk factors related to family and school among adolescents in China. *Addictive Behaviors Reports, 7,* 14–18. http://dx.doi.org/10.1016/j.abrep.2017.10.003

Xing, L., Yuan, K., Bi, Y., Yin, J., Cai, C., Feng, D., . . . Tian, J. (2014). Reduced fiber integrity and cognitive control in adolescents with internet gaming disorder. *Brain Research, 1586,* 109–117. http://dx.doi.org/10.1016/j.brainres.2014.08.044

Yang, H., Yao, S., Zhu, X., Randy, P. A., John, R. Z. A., & Xi, T. (2007). The Chinese Version of the Barratt Impulsiveness Scale, 11th Version (BIS-11) in adolescents: Its reliability and validity. *Chinese Journal of Clinical Psychology, 15,* 4–6. http://dx.doi.org/10.3969/j.issn.1005-3611.2007.01.002

Yao, Y., Chen, P., Li, C. S. R., Hare, T. A., Li, S., Zhang, J., . . . Fang, X. Y. (2017). Combined reality therapy and mindfulness meditation decrease intertemporal decisional impulsivity in young adults with Internet gaming disorder. *Computers in Human Behavior, 68,* 210–216. http://dx.doi.org/10.1016/j.chb.2016.11.038

Yao, Y. W., Chen, P. R., Chen, C., Wang, L. J., Zhang, J. T., Xue, G., . . . Fang, X. Y. (2014). Failure to utilize feedback causes decision-making deficits among excessive Internet gamers. *Psychiatry Research, 219,* 583–588. http://dx.doi.org/10.1016/j.psychres.2014.06.033

Yao, Y. W., Chen, P. R., Li, S., Wang, L. J., Zhang, J. T., Yip, S. W., . . . Fang, X. Y. (2015). Decision-making for risky gains and losses among college students with Internet gaming disorder. *PLOS ONE, 10,* e0116471. http://dx.doi.org/10.1371/journal.pone.0116471

Yao, Y. W., Wang, L. J., Yip, S. W., Chen, P. R., Li, S., Xu, J., . . . Fang, X. Y. (2015). Impaired decision-making under risk is associated with gaming-specific inhibition deficits among college students with Internet gaming disorder. *Psychiatry Research, 229,* 302–309. http://dx.doi.org/10.1016/j.psychres.2015.07.004

Yip, S. W., Desai, R. A., Steinberg, M. A., Rugle, L., Cavallo, D. A., Krishnan-Sarin, S., & Potenza, M. N. (2011). Health/functioning characteristics, gambling behaviors, and gambling-related motivations in adolescents stratified by gambling problem severity: Findings from a high school survey. *The American Journal on Addictions, 20,* 495–508. http://dx.doi.org/10.1111/j.1521-0391.2011.00180.x

Young, K. S. (1998). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology & Behavior, 1,* 237–244. http://dx.doi.org/10.1089/cpb.1998.1.237

Young, K. S. (2009). Understanding online gaming addiction and treatment issues for adolescents. *American Journal of Family Therapy, 37,* 355–372. http://dx.doi.org/10.1080/01926180902942191

Yu, F., & Chan, K. (2012). Assessment of operating performance of chiller systems using cluster analysis. *International Journal of Thermal Sciences, 53,* 148–155. http://dx.doi.org/10.1016/j.ijthermalsci.2011.10.009

Yuan, K., Qin, W., Yu, D., Bi, Y., Xing, L., Jin, C., & Tian, J. (2016). Core brain networks interactions and cognitive control in internet gaming disorder individuals in late adolescence/early adulthood. *Brain Structure & Function, 221,* 1427–1442. http://dx.doi.org/10.1007/s00429-014-0982-7

Zhou, Z. H., Yuan, G. Z., Yao, J. J., Li, C., & Cheng, Z. H. (2010). An event-related potential investigation of deficient inhibitory control in individuals with pathological Internet use. *Acta Neuropsychiatrica, 22,* 228–236. http://dx.doi.org/10.1111/j.1601-5215.2010.00444.x

Zuckerman, M., Eysenck, S., & Eysenck, H. J. (1978). Sensation seeking in England and America: Cross-cultural, age, and sex comparisons. *Journal of Consulting and Clinical Psychology, 46,* 139–149. http://dx.doi.org/10.1037/0022-006X.46.1.139

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