Decision-Making and Prepotent Response Inhibition Functions in Excessive Internet Users

By De-Lin Sun, PhD, Zu-Ji Chen, BS, Ning Ma, BS, Xiao-Chu Zhang, PhD, Xian-Ming Fu, BS, and Da-Ren Zhang

ABSTRACT

Introduction: Excessive Internet use (EIU), also described as Internet addiction or pathological Internet use, has already become a serious social problem around the world. Some researchers consider EIU as a kind of behavioral addiction. However, there are few experimental studies on the cognitive functions of excessive Internet users (EIUers) and limited data are available to compare EIU with other addictive behaviors, such as drug abuse and pathological gambling.

Methods: In this study, we examined EIUers’ functions of decision-making and prepotent response inhibition. Two groups of participants, EIUers and controls, were compared on these functions.

FOCUS POINTS

- Excessive Internet use has already become a serious social problem around the world. However, limited data from experimental studies are available on cognitive functions of excessive Internet users (EIUers).
- EIUers and normal controls were compared on decision-making and prepotent response inhibition functions by using a Gambling Task and a Go/no-go Task, respectively.
- Compared with controls, EIUers performed worse in the Gambling Task, and made progress more slowly in selecting strategy. However, EIUers performed better in the Go/no-go Task.
- These results indicated EIUers have deficits in decision-making function, which are characterized by a strategy learning lag rather than an inability to learn from task contingencies. More studies were needed to examine EIUers’ inhibition function and more specific assessments for this function.
two functions by using a Gambling Task and a Go/no-go Task, respectively.

Results: Compared with controls, EIUers selected significantly less net decks in the Gambling Task ($P = .007$). Furthermore, the EIUers made progress in selecting strategy, but more slowly than did the control group (EIUers, chunk 3 > chunk 1, $P < .001$; controls, chunk 2 > chunk 1, $P < .001$). Interestingly, EIUers’ accuracy during the no-go condition was significantly higher than that of controls ($P = .018$).

Conclusion: These results showed some similarities and dissimilarities between EIU and other addictive behaviors such as drug abuse and pathological gambling. The findings from the Gambling Task indicated that EIUers have deficits in decision-making function, which are characterized by a strategy learning lag rather than an inability to learn from task contingencies. EIUers’ better performance in the Go/no-go Task suggested some dissociation between mechanisms of decision-making and those of prepotent response inhibition. However, EIUers could hardly suppress their excessive online behaviors in real life. Their ability of inhibition still needs to be further studied with more specific assessments.

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INTRODUCTION

Excessive Internet use (EIU), also described as Internet addiction1-2 or pathological Internet use,3 is defined as an individual’s inability to control his or her use of the Internet, which eventually causes psychological, social, academic, and/or work difficulties in life.4 EIU has already become a serious worldwide social problem and has attracted much attention from psychologists, educators, and the public.4-6 Some researchers suggest that EIU is a kind of behavioral addiction.1-2 By using survey approaches, several studies focused on aspects such as assessment criteria, epidemiology, and psychiatric comorbidity of EIU.7-9 However, limited data from experimental studies are available on cognitive functions of excessive Internet users (EIUers); such studies may provide the development of EIU treatment and prevention strategies. In the present study, behavioral tasks are used to compare cognitive abilities between EIUers and controls. Moreover, EIUers’ behavior is much like that of drug abusers’ and pathological gamblers’.2 Thus, cognitive links between EIU and other addictive behaviors were also discussed.

EIUers persist in pursuing immediate Internet usage (eg, excessive gaming, sexual activity preoccupations, and e-mail/text messaging6) even though they are aware of the long-term negative consequences of these actions to their normal lives. This myopia for the future may be attributed to impaired decision-making function, which reflects a process in which a choice is made after reflecting on the consequences of that choice.10 The Gambling Task used by Bechara and colleagues21 is able to detect and measure participants’ decision-making function via testing the ability to balance immediate rewards against long-term negative consequences. Several studies have demonstrated decision-making impairment in substance abusers12-14 and pathological gamblers15,16 by using this task.

Besides decision-making, EIUers may also be impaired in the ability of prepotent response inhibition, which represents the ability of deliberately suppressing dominant, automatic, or prepotent responses.16,17 For example, EIUers usually stay online longer than intended.2,8 Deficits in the ability of inhibiting prepotent responses can be assessed by the Go/no-go Task, a widely used paradigm.18,19 In this task, participants meet much more go conditions than no-go conditions, thereby creating a response prepotency that is difficult to inhibit in the no-go condition. Previous studies using this task have demonstrated deficits in inhibitory ability in substance abusers20,21 and pathological gamblers.22

In the present study, we examined EIUers’ cognitive functions of decision-making and prepotent response inhibition, respectively. We hypothesized EIUers would be impaired on these two functions just as those drug abusers or pathological gamblers are.
METHODS

Participants and Assessment
We recruited graduate and undergraduate students at the University of Science and Technology of China (USTC) for a study of online behaviors. This study was approved by the Ethical Committee of USTC. All participants gave informed consent before the experiments and received monetary compensation after the experiments for their time spent in this study. None of the participants reported having a history of drug abuse, head injury, or diagnosed psychiatric/neurological disorders.

Participants were screened with the Young’s Internet addiction questionnaire, which is a widely used criterion for Internet addiction. It is an eight-item questionnaire adapted from the Diagnostic and Statistic Manual of Mental Disorders, Fourth Edition criteria for pathological gambling. The questionnaire was translated into Chinese by the researchers. In accordance with Young, participants who answered “yes” to five or more items (EIU scores ≥5) were classified as EIUers and the remainder (EIU scores <5) were classified as normal controls. Fifty-two EIUers (10 females) and 61 control participants (11 females) were included in the present study.

Testing Procedure
Participants were tested individually. After finishing the Young’s questionnaire and a demographic questionnaire, they performed a Gambling Task and then a Go/no-go Task. There was a two-minute break between these two tasks to avoid fatigue. Other tasks and questionnaires were also administered (those results will be reported elsewhere). It took no more than 1 hour to complete the entire testing session.

Gambling Task
A modified version of the Gambling Task based on the description in the literature was employed in the present study. We made two modifications. First, we prolonged the task from 100 trials, in the standard Gambling Task, to 180 trials in order to study the learning curve of participants. Second, no monetary reward was used. Instead, participants were motivated by a system in which more points gained indicated better cognitive abilities. According to our pilot study, students prefer proving self abilities to gaining small amounts of money in experimental studies. In each trial, four decks were presented on the screen. With each deck chosen, participants were informed that they had won/lost a particular amount of points. The decks differed in their payoff schedules. In terms of amount won, Decks A and B were similar to each other with a payoff of 100 points each. Decks C and D were also similar to each other with a payoff of 50 points each. In terms of the intermittent penalties, Deck A led to a penalty of 250 points, which occurred on ~50% of trials, while Deck B led to a penalty five times larger, but ~20% as frequently. Deck C led to a penalty of 50 points and occurred on ~50% of trials, while Deck D led to a penalty five times larger but ~20% as frequently. The average payoff for Decks C and D were positive (referred to as “good decks”). In contrast, the average payoff for Decks A and B were negative (referred to as “bad decks”).

Each participant received 3,000 points at the beginning of the formal task. Participants were instructed to gain as many points as possible by selecting one deck at a time from each of the four decks (from A to D). Participants had no ideas of the number of trials in the task. Before the formal task, participants read instructions and performed four practice trials. These practice trials did not include information about payoffs of the decks or total trial numbers in the formal task. A net global outcome score (net decks) for each chunk of 60 trials (ie, chunk 1, 2, and 3, including trials 1–60, 61–120, and 121–180, respectively) was calculated by subtracting the total number of the bad decks (ie, Decks A and B) selected from the total number of the good decks (ie, Decks C and D) selected.

Go/No-go Task
At the beginning of each trial, a white cross was presented at the center of the black screen for 200 ms, and then a number (from 0–9) replaced the cross for another 200 ms. After that, a black square with white strips masked the number and lasted 500 ms. Participants were instructed to withhold if the number was 2 or 6 (ie, no-go condition) but respond with a key press as quickly as possible to the other numbers (ie, go condition). Each participant performed 10 practice trials and then 120 formal trials. Ratio of go trials to no-go trials was 4:1. Accuracy of go and no-go conditions and reaction time of go condition were analyzed. Three EIUers’ data were missed because of technical problems in the data acquisition.
RESULTS

Demographic Data

The two groups of participants did not differ significantly in gender (x²(1))=.027, P>.05), age (18–29 years; EIU: 21.5±2.3 years; control: 20.7±2.1 years, t(111)=1.842, P>.05) or monthly expenditure (EIU: ¥575.4±195.0; control: ¥554.9±195.5, t(110)=.553, P>.05; one EIU refused to report this item).

Compared with control participants, EIUers spent more time on the Internet (averaged during the past year, EIU: 20.4±16.0 hours/week; control: 5.9±11.0 hours/week, t(86.8)=5.453, P<.001; one EIUer and two control participants refused to report this item), and showed less satisfaction with their own lives (self-reporting scale from –10 “extremely bad” to 10 “extremely good,” EIU: 1.0±5.4; control: 4.2±4.7, t(101.7)=–3.378, P=.001).

All EIUers and some control participants were computer game players (online and/or offline) who reported having played computer games during the past year. Some of these players reported time spent on computer games (averaged during the past year). EIUers (n=27, 9.7±12.4 hours/week) spent significantly more time on computer games than control participants (n=30, 3.9±3.8 hours/week), t(30.5)=2.324, P=.027. Participants’ most favorite game types included intense real-time strategy games (StarCraft, Warcraft III, etc.), first person shooting games (Counter-Strike, Quake III, etc.), sports games (Free Style, etc.), and massive multi-player online games (World of Warcraft, etc.). All of these are action or action-like games, which need players to control their behaviors accurately.

Gambling Task

A repeated measure analysis of variance (ANOVA) was employed to analyze the net decks, with chunk (chunk 1, 2, and 3) as the within-participant factor, and group (control and EIU) as the between-participant factor. The result showed significant main effects of chunk (F(2,102)=9.745, P<.001, Greenhouse-Geiser corrected) and group (F(1,111)=7.624, P=.007). The interaction between chunk and group was also significant (F(2,102)=3.296, P=.043, Greenhouse-Geiser corrected). Post-hoc analysis (Bonferroni corrected) between groups in each of the 3 chunks showed that EIUers selected significantly more net decks than control participants in chunk 2 (t(111)=–3.472, P=.003), as shown in Figure 1. No significant group differences were found in either chunk 1 (t(111)=–1.144, P>.05) or chunk 3 (t(111)=–2.010, P>.05).

Two partial correlation analyses were conducted to examine the relationship between net decks in each chunk and participants’ EIU scores, and the relationship between net decks in each chunk and time spent on the Internet, respectively. Gender, age, monthly expenditure, and life satisfaction entered into these partial correlation analyses as control variables. The result showed that net decks in chunk 2 correlated significantly with the extent participants indulged in the Internet (ie, EIU scores: Correlation coefficient=–0.280, P=.003), as shown in the Table. No other significant correlations were found between net decks in chunk 1 or 3 and participants’ EIU scores, or between net decks in each chunk and the time spent on the Internet, as shown in the Table.

We also employed one way ANOVA to analyze the net decks selected in each group separately with chunk (chunk 1, 2, and 3) as the within-participant factor. Participants in both groups selected more net decks with the increase of chunk numbers (control, (F(1.6,93.4)=25.611, P<.001, Greenhouse-Geiser corrected); EIU (F(2,102)=9.745, P<.001). Pairwise comparisons (post-hoc analysis, Bonferroni corrected) between chunks in each group showed that control participants selected significantly more net decks in both chunk 2 (t(60)=5.657, P<.001) and chunk 3 (t(60)=5.496, P<.001) than those in chunk 1, and no significant difference were found between

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Control variables: gender, age, monthly expenditure and life satisfaction.

* P<.01.

EIU=excessive Internet use; Corr. Coef.=correlation coefficient.

chunk 3 and chunk 2 (t(60)=1.508, P=.410). EIUers selected more net decks in chunk 3 than those in both chunk 1 (t(51)=4.351, P<.001) and chunk 2 (t(51)=2.868, P=.018), and no significant difference were found between chunk 2 and chunk 1 (t(51)=1.538, P=.390). These results showed, compared with chunk 1, control participants selected significantly more net decks in chunk 2, whereas EIUers selected significantly more net decks in chunk 3. It demonstrated that EIUers were more slowly than control participants to make significant progress in selecting strategy (Figure 1).

Go/No-go Task
A repeated measure ANOVA was employed to analyze the accuracy of the Go/no-go Task, with group (EIU and control) as the between-participant factor, and Go/no-go (go and no-go) as the within-participant factor. The results showed significant main effect of Go/no-go (F(1,108)=155.367, P<.001) and significant interaction of Go/no-go with group (F(1,108)=5.793, P=.018). However, the main effect of group was not significant (F(1,108)=2.019, P=.158). EIUers’ accuracy of no-go trials was significantly higher than that of control participants (t(108)=2.392, P=.018), while the accuracy and reaction time of go condition were not significantly different between the two groups (accuracy, t(108)=0.765, P=0.446; reaction time, t(108)=0.889, P=0.376) (Figure 2).

DISCUSSION
EIUers selected significantly less net decks than control participants in the Gambling Task. This result indicated that EIUers’ ability of decision-making was diminished. They had difficulties in balancing immediate rewards against long-term negative consequences, similar to substance abusers12,13 and pathological gamblers.15,27 However, EIUers did not always make improper decisions. Though changing selecting strategy more slowly, EIUers still demonstrated a learning curve, and their net decks selected in the last chunk were not significantly less than that of control participants’. It suggested that the decision-making impairment of EIUers is a strategy learning lag rather than an inability to learn from task contingencies. This is also similar to findings in previous studies of substance abusers.13,24 Therefore, our study affords experimental evidence supporting the hypothesis that there is a link between EIU and other addictive behaviors.2,25,26

FIGURE 1.
Gambling Task Performance (Net Decks)

Net decks ((C+D)-(A+B)) in each chunk of the Gambling Task. EIUers selected significantly less net decks in chunk 2 (P=.003) than control participants. Both groups selected more net decks with increasing number of chunks. However, EIUers were later than control participants to make significant progress in selecting strategy (ie, compared with chunk 1, control participants selected significantly more net decks in chunk 2 (P<.001), whereas EIUers selected significantly more net decks in chunk 3 (P<.001). ** P<.01, t-test between groups for each chunk; *** P<.001, t-test between chunks within each group. All these comparisons were corrected (Bonferroni correction) for multiple tests. Error bar denotes SEM. EIU=excessive Internet use; CON=control; EIUers=excessive internet users; SEM=standard error mean.


FIGURE 2.
Go/No-go Task performance

A. Accuracy of go and no-go conditions. EIUers had significantly higher accuracy of no-go condition than control participants (P=.018), while the accuracy of go condition was not significantly different between the two groups (P=.446). B. Reaction time of go condition. There was no significant difference on reaction time of go condition between the two groups (P=.376). * P<.05, t-test between groups. Error bar denotes SEM. EIU=excessive Internet use; CON=control; ms=milliseconds; EIUers=excessive internet users; SEM=standard error mean.

From a clinical point of view, decision-making tasks, such as the Gambling Task, might be used as neuropsychological tests to assess EIUers’ cognitive functions and evaluate related clinical and treatment approaches. Furthermore, previous studies demonstrated that Gambling Task performance was related with functions of several brain structures, especially the ventromedial prefrontal cortex and amygdala. Our results may reflect functional alterations in these structures in EIUers, and provide compelling evidence of the necessity to assess the functional status of these structures (eg, using functional neuroimaging). Previous studies showed that patients with perpetual lesions in ventromedial prefrontal cortex or amygdala could no longer learn from the consequences of their decisions anymore. However, we found that EIUers could, though more slowly than normal controls, make some progress in decision-making. This finding might have important implications for the rehabilitation of EIUers who may benefit from specific training in decision-making skills.

Some researchers suggested that response inhibition is a part of decision-making function. Impaired decision-making as measured by the Gambling Task may be explained by impaired response inhibition. Indeed, besides decision-making deficits, previous studies also showed impaired abilities of prepotent response inhibition in substance abusers and pathological gamblers. However, surprisingly and interestingly, we found that in the Go/no-go Task, EIUers’ accuracy of the no-go condition was significantly higher than that of control participants. That is to say, compared with control participants, EIUers can perform better to inhibit some kinds of prepotent responses though they make poor decisions. This result suggests that there may be some dissociation between mechanisms of decision-making and those of prepotent response inhibition. It is consistent with Bechara’s point. He argued that response inhibition is fundamentally different from decision-making. Compared with the former, the latter as exemplified in the Gambling Task paradigm involves “a dilemma that requires evaluation of pros and cons of various response options (ie there is no easy answer) and, most importantly, the outcome of a given action is uncertain and unpredictable.”

Though they performed better in the Go/no-go Task, EIUers could hardly inhibit their prepotent response of using the Internet in real life, which is a critical problem in EIUers. It seems that in theory, the prepotent response inhibition may not be unitary; instead, it includes two subtypes: one is to inhibit Internet-unrelated responses, and the other is to suppress Internet-related responses. EIUers have better ability in the former one, but are impaired in the latter one. The commonly used Go/no-go Task could not reflect EIUers’ deficits in inhibiting their prepotent responses from using the Internet. Thus, a more specific inhibition task is needed. A well-designed inhibition task including Internet-related cues may be a good candidate. This notion is supported by previous studies that drug-related or gambling-related cues can change activations in neural circuits of motivation and cognitive control (even when the cues are presented unconsciously), which contributes to an inability to inhibit the compulsive behaviors of drug taking or gambling. A recent electroencephalographic study comparing excessive computer game players with casual players also showed significant between-group differences in event-related potentials evoked by computer game-related cues. Therefore, cues related to Internet use may also influence EIUers’ performance in inhibition tasks.

Symptoms of disinhibited behavior are shared by many addictive behaviors. However, EIUers showed a much different performance pattern in the inhibition task. A possible explanation of this specific result is that EIUers have benefited from more computer game playing experience than did control participants. Some computer games (especially those action or action-like games, which were the favorites of participants in the present study and of most Chinese computer game players), require players to control their behaviors accurately, (eg, Counter Strike or Quake III needs players to inhibit their prepotent responses of shooting when they aim at partners). Compared with control participants, EIUers in our study spent significantly more time on computer games; therefore, they practiced more in games and might do better in inhibiting some kinds of prepotent responses in some cases. Previous studies have already shown that practice on some computer games improves players’ abilities related to motor, perception, and selective attention. More efforts are needed to test whether and how computer games influence EIUers’ abilities of inhibition.
CONCLUSION

The present study was a preliminary research in EIUers’ cognitive functions. Our data showed that compared to control participants, EIUers had deficits on the decision-making function and they improved their selecting strategy more slowly. However, surprisingly, EIUers performed better in the Go/no-go Task, a popular test to measure the function of prepotent response inhibition. These results showed similarities and dissimilarities between EIU and other addictive behaviors, and had theoretical and clinical implications. Moreover, additional research is needed to examine the influence of age, gender, and culture on EIUers’ behaviors. 

REFERENCES


Original Research

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