FULL-LENGTH REPORT

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Physiological markers of biased decision-making in problematic Internet users

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Background and aims: Addiction has been reliably associated with biased emotional reactions to risky choices. Problematic Internet use (PIU) is a relatively new concept and its classification as an addiction is debated. Implicit emotional responses were measured in individuals expressing nonproblematic and problematic Internet behaviors while they made risky/ambiguous decisions to explore whether they showed similar responses to those found in agreed-upon addictions. *Methods:* The design of the study was cross sectional. Participants were adult Internet users (N = 72). All testing took place in the Psychophysics Laboratory at the University of Bath, UK. Participants were given the Iowa Gambling Task (IGT) which provides an index of an individual's ability to process and learn probabilities of reward and loss. Integration of emotions into current decision-making frameworks is vital for optimal performance on the IGT and thus, skin conductance responses (SCRs) to reward, punishment, and in anticipation of both were measured to assess emotional function. *Results:* Performance on the IGT did not differ between the groups of Internet users. However, problematic Internet users expressed increased sensitivity to punishment as revealed by stronger SCRs to trials with higher punishment magnitude. *Discussion and conclusions:* PIU seems to differ on behavioral and physiological levels with other addictions. However, our data imply that problematic Internet users were more risk-sensitive, which is a suggestion that needs to be incorporated into in any measure and, potentially, any intervention for PIU.

Keywords: problematic Internet use, decision-making, skin conductance response

INTRODUCTION

In recent years, the usage of Internet has enormously increased with most users enjoying the benefits that varied online applications offer (Office for National Statistics, 2014). However, for a minority of individuals, the use of Internet is problematic (Caplan, 2007; Yen et al., 2008). Following Brown's (1991, 1993) proposed criteria for behavioral addictions and DSM-5 (American Psychiatric Association, 2013) definition of mental health disorder, problematic Internet use (PIU) can be defined as a set of maladaptive behaviors and cognitions, which are associated with excessive Internet use and result in significant negative repercussions in the person's life. A pitfall in this arena is the way researchers use the term "PIU" interchangeably to describe behaviors, which are associated with computer usage, gaming, social networking, etc. This has created confusion as to whether all these types of activities can be associated with a similar set of behaviors and whether the Internet is just the medium to pursue an already problematic behavior. Researchers have gone further and questioned whether it is the Internet per se or certain applications that are responsible for individuals displaying PIU (Davis, 2001; Griffiths, 1999, 2000; Stern, 1999; Yellowlees & Marks, 2007; Young, 1999). This study is not concerned whether a problematic Internet user uses the Internet, for example, for social networking sites, would also spend time on other online applications. Instead, it could be argued that there might exist problematic Internet users whose Internet use is specific or generic (Davis, 2001). The necessity for PIU is to associate with Internet activities that can only be found online.

Emerging evidence suggests that there exist similarities in the mechanisms underlying PIU and other addictions (in particular, substance dependence and pathological gambling) on a behavioral (Grant, Potenza, Weinstein, & Gorelick, 2010; Yen, Yen, Chen, Chen, & Ko, 2007) and neurobiological level (Dong & Zhou, 2010; Yuan et al., 2011). Furthermore, research has revealed a high comorbidity between them (Yen et al., 2007, 2008; Villella et al., 2010), all suggesting that they share a similar pathogenesis and symptomology (Shaffer et al., 2004). However, further work is required to establish firmer conclusions as to whether such similarities hold true for the many biases reliably seen in addiction. Researching this area will significantly impact our understanding of whether PIU is another type of behavioral addiction and enrich our recognition of the potential mechanisms associated with its development and maintenance.

PIU is characterized by persistence in continuing to use the Internet despite the rise of negative consequences in the user's life (such as neglect of everyday activities and social life, problems with intimate and social relationships, etc.).

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This type of behavior can be viewed as resembling that of addicted individuals consuming substances or gambling even though they know that these actions will have adverse consequences on themselves and others around them. Addicted individuals have what has been termed "myopia for the future" (Bechara & Damasio, 2002), where they express biases in decision-making by ignoring the negative outcomes of their behavior. This has been linked with the maintenance of the addiction cycle (Bechara & Damasio, 2002; Bechara, Dolan, & Hindes, 2002; Brand et al., 2005; Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005, 2006; Verdejo-García & Bechara, 2009; Verdejo-Garcia et al., 2007). The discovery of such biased functioning in individuals with PIU will elucidate whether PIU should be considered as part of the addiction spectrum.

A widely used task to assess decision-making function is the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Lee, 1999). In the IGT, unknown outcomes must be learned through repeated exposure and an appropriate self-controlled strategy must be employed leading to an overall gain (Bechara et al., 1999). Generation of implicit emotion-related signals, which are expressed physiologically (somatic markers [SMs]), provide a "gut feeling" about the emotional valence of an anticipated outcome and are necessary in helping guide our decisions (Damasio, 1994). In the IGT, impaired generation of SMs, as indexed by the level of physiological emotional arousal manifested through skin conductance responses (SCRs), is associated with poorer performance (i.e., higher losses) (Bechara & Damasio, 2002; Bechara et al., 1999, 2002; Goudriaan et al., 2006). Poorer performance by addicts, underpinned by impaired SMs, is a hallmark of addiction and is related to a broader dysfunctional emotional system, which has significant effects on choice behavior (Verdejo-García & Bechara, 2009).

This study assesses whether blunted SMs are associated with PIU, elucidating, thus, the underlying mechanisms that might be involved in its development and/or maintenance as well as exploring potential similarities in biological functioning between PIU and other addictions. To the best of our knowledge, only two studies have assessed the decision-making processes in PIU with the IGT, but they lacked physiological assessment; therefore, an understanding of SMs is currently absent (Ko et al., 2010; Sun et al., 2009). Moreover, there was a discrepancy in the findings in relation to task performance. Sun et al. (2009) found that problematic Internet users' overall performance was impaired compared with controls, whereas Ko et al. (2010) found that they performed better than controls. These discrepancies could be due to differences in methodology between the two studies (number and ethnicity of participants, assessment tools, and number of trials on IGT). However, the lack of physiological assessment (SCRs) in both studies makes it impossible to assess SMs and thus lead to possible explanation of the discrepancies between studies. For example, despite reliable findings that substance-dependent individuals show poorer performance on the IGT, there is a subgroup that shows equal levels of performance and SCRs to that of controls (Bechara et al., 2002). In contrast to the better performing subgroup, the poorer performing subgroups expressed either blunted anticipatory SMs or enhanced reward sensitivity and decreased sensitivity to punishment (stronger SCRs before and after they made a choice with a higher reward and weaker SCRs after a choice with a higher punishment) (Bechara et al., 2002). These findings reveal biases in the processes underlying decision-making and highlight the necessity for SCRs assessment.

Addictive behaviors have been associated with various psychological problems including depression, anxiety, etc. (DuPont, 1995; Johnson, 2009; Moore et al., 2007). Another objective of this study is to assess whether elevated levels of psychopathology are evident in healthy volunteers ranging in their Internet use from mild to excessive problematic. Researching the area will further clarify on the potential similarities between PIU and addictive behaviors. Furthermore, it could illustrate whether it is possible to differentiate between healthy and PIU with reference to potential psychopathological differences between them.

This study investigates whether reliably found behavioral and physiological markers of addiction are also characteristics of PIU, thus providing further evidence regarding whether PIU should be classified within the addiction spectrum. Based upon the studies conducted with substance-dependent individuals and pathological gamblers (Bechara & Damasio, 2002; Bechara et al., 2002; Goudriaan et al., 2006; Verdejo-García & Bechara, 2009), it is hypothesized that problematic Internet users will show impaired performance on the IGT compared with non-problematic users and that this performance is associated with blunted somatic activation (impairment in the generation of anticipatory SCRs).

METHODS

Participants

A total of 72 participants (27 males) between the ages of 23 and 41 [mean (*M*) age = 23.08 years, standard deviation (*SD*) = 4.61] were recruited from UK. All participants filled in a battery of questionnaires on an online data collection website (the Bristol Online Survey) and conducted a lab-based experiment (IGT). There was an imbalance in the male-to-female ratio in this study; however, this imbalance was similar for both non-problematic and problematic Internet users (ratio 1:1.7). All participants received £10 reimbursement (see Tables 1 and 2 for more details).

Measures

Problematic Internet Use Questionnaire (PIUQ). The PIUQ is an 18-item self-report questionnaire (Demetrovics, Szeredi, & Rozsa, 2008) assessing problems arising from Internet use. PIUQ was not developed to assess the clinical symptoms that related to excessive Internet use, and thus, its scale items do not translate into clinical issues. The PIUQ has three subscales: obsession, neglect, and control disorder. The Cronbach's α coefficient was 0.93. Demetrovics et al. (2008) have proposed a cut-off score higher than 52.2 with a $M = 59.4$ and $SD = 5.3$ for Internet users with significant problems. Following Demetrovics suggestion, two groups of Internet users were created: one group scoring below 52 (non-problematic Internet users) and other group scoring

Table 1. Demographics and psychopathological characteristics for non-problematic and problematic Internet users

	Non-problematic Internet users ($N = 45$)		Problematic Internet users ($N = 27$)			
	M	*SD*	*M*	*SD*	t/X^2	*p*
Gender						
Male	37.8%		37%			
Female	62.2%		63%			
Age	23.3	4.9	22.7	4.1		
PIUQ	37.5	9.6	59.7	5.8		
Occupation						
Student	75.5%		96.3%			
Employee	24.5%		3.7%			
Means for assessing the Internet						
Computer/laptop	93.3%		100%			
Mobile	6.7%					
Psychopathological comorbidity						
Depression	26.7%		29.6%		0.07	.79
Suicide attempt/deliberate self-harm	8.9%		3.7%		0.70	.64
Manic episode/manic depression/bipolar disorder	2.2%		3.7%		0.14	1.00
Anxiety/panic/phobia	15.6%		14.8%		0.01	1.00
Obsessive–compulsive disorder	4.4%		0%		1.23	.52
Psychotic episode/schizophrenia	0%		3.7%		1.70	.37
Eating disorders	2.2%		7.4%		1.30	.55
Drug and alcohol problems	4.4%		3.7%		0.02	1.00
Other	2.2%		3.7%		0.14	1.00
Psychopathological symptoms	0.67	1.0	0.70	1.1	−0.15	.88

Table 2. Correlations (Pearson) between non-problematic and problematic Internet users with quantity of time spent on various online applications/activities

	Non-problematic Internet user		Problematic Internet user	
Online activity	Rho value	*p*	Rho value	*p*
Searching information for goods or services	−.04	.80	−.54	**.004****
Reading and writing e-mails	−.141	.35	−.25	.21
Playing online games	.44	**.002****	.33	.09
Downloading software	.18	.25	−.33	.10
Communicating with friends	.12	.44	−.25	.21
Keeping track of new developments in areas of personal interest	.13	.39	−.13	.50
Downloading information	.24	.11	−.04	.83
Reading and posting messages on newsgroup/discussion groups	.33	**.02***	.29	.14
Meeting new online friends	.33	**.02***	.12	.55
Updating personal homepage	.25	.10	−.08	.70
Seeking advice from professionals	.18	.24	−.12	.54
Communicating with online friends	.44	**.002****	−.38	**.04***
WWW-surfing and browsing	.32	**.03***	.33	.10
Participating in discussion	.21	.16	.22	.27
Buying goods online	−.12	.42	.03	.90
Meeting new people for romantic relationships	.26	.09	−.21	.29
Watching video content	.32	**.03***	.23	.24
Online gambling	.30	**.046***	−.06	.76

Note. Values are correlation coefficients; bold coefficients are statistically significant (two-tailed).
*$p < .05$, **$p < .01$.

above 52 (problematic Internet users; see Table 1 for details on PIUQ scores).

Questionnaire assessing psychopathological comorbidity. Participants were explicitly asked whether they had ever had (a) depression, (b) attempted suicide/deliberately self-harmed, (c) manic episode/manic depression/bipolar, (d) anxiety/panic/phobia, (e) obsessive compulsive disorder, (f) psychotic episode/schizophrenia, (g) eating disorders,

(h) drug and alcohol problem, and (i) other psychopathology. A score of either 0 (*absent*) or 1 (*present*) was assigned (see Table 1 for prevalence rates).

Questionnaire assessing Internet-related activities. An 18-item self-report questionnaire assessing engagement with specific online applications was based on questions similar to those generated by Van Rooij (2011) and studies of Eijnden, Meerkerk, Vermulst, Spijkerman, and Engels (2008). Respondents rated each item on a 4-point scale (1, never; 2, rarely; 3, sometimes; and 4, often). The Cronbach's α coefficient for the current sample was 0.80 (see Table 2 for more details).

Brief Symptom Inventory (BSI-53). The Brief Symptom Inventory (BSI) is a 53-item self-report questionnaire assessing the levels of psychopathology (Derogatis & Melisaratos, 1983). The BSI-53 consists of nine subscales: somatization, obsessive–compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism. The BSI also contains three global indices of distress: the General Severity Index, the Positive Symptom Total, and the Positive Symptom Distress Index. The BSI-53 has good internal consistency with a range of 0.71–0.85, and test–retest reliability with a range of 0.68–0.91 (Derogatis & Melisaratos, 1983). All the raw scores were converted to T-scores using adult non-patient norms for each gender (Derogatis, 1993). The Cronbach's α coefficient was 0.96.

Iowa Gambling Task. A computerized version of the original IGT was used (Bechara et al., 1999). In 100 trials, participants could choose between decks of cards that differed in magnitude of rewards and punishments. Two decks of cards (decks A and B) were associated with higher immediate rewards but led to greater loss in the long term (termed "disadvantageous"), and two decks of cards (decks C and D) were associated with lower immediate rewards but led to greater gain in the long term (termed "advantageous"). The goal of the task was to learn deck contingencies to win as much hypothetical money as possible. Participants were initially unaware of the contingencies of the cards. In each trial, participants were given the four cards face down from which they chose one. Following the choice, feedback was given on the amount won and lost, if applicable, for 6 s in line with established methodology (Bechara et al., 1999). The dependent variables for IGT performance were the total number of cards selected from advantageous minus disadvantageous decks within blocks of 20 trials (five blocks) to assess the rate of learning of the contingencies of the decks.

Skin Conductance Responses. In this study, SCRs were acquired using a Biopac MP150. The sampling rate was 1,000 samples/second. Reusable electrodes (Ag/AgCl) filled with electrolyte gel (NaCl) were placed in the distal phalanges of the index and middle fingers of the non-dominant hand and the following three types of SCR were measured: reward SCRs, generated after turning a card for which there was a reward; punishment SCRs, generated after turning a card for which there was a penalty; and anticipatory SCRs, generated prior to turning a card from any given deck. Event-related analysis was used to analyze SCRs. The time window for the reward and punishment SCRs was set from the 2nd second after participants made a response until the 5th second and for anticipatory SCRs was set from the end of the 6th second (where the four decks of cards appeared on the screen and another choice could be made) for a duration of 3 s. Thus, for each participant, we obtained two dependent variables for reward, punishment, and anticipatory SCRs, respectively (for advantageous decks and disadvantageous decks).

Data analysis

Whether frequency of punishment had an effect on task performance between the two groups of Internet users was assessed. No difference for higher frequency punishment decks [A and C: $t(70) = 0.78$, $p = .44$] and lower frequency punishment decks [B and D: $t(70) = -0.78$, $p = .44$] was observed. Thus, this analysis focused only on task performance between disadvantageous (A and B) and advantageous (C and D) decks. IGT performance of the two groups was assessed with a 2 (groups) × 5 (blocks) mixed analysis of variance (ANOVA), followed up with post-hoc tests to identify the differences in performance between the blocks on the IGT. Each block consisted of 20 trials (five blocks) to assess the learning rate regarding the contingencies of the decks. Sample size ($N = 72$) accounted for a 96% power in this study for detecting a medium-sized effect.

Because of technical difficulties, seven participants had no SCR data and thus were excluded from further analysis related to physiological assessment; however, their behavioral data were usable. Furthermore, data were excluded from the analysis, when they were deviating more than three times the interquartile range from 25th or 75th percentile (2.8% of the data) to control for movement artifacts and when there was a missing value for that particular event (9.7% of data). Mann–Whitney and Wilcoxon tests (because SCR data violated parametric assumptions, i.e., highly skewed with high levels of kurtosis) assessed between- and within-group differences on SCRs data, respectively. Two-tailed analysis was followed throughout.

Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. The Institutional Review Board of the Department of Psychology, University of Bath, approved this study. All participants were informed about the study and all provided informed consent.

RESULTS

Psychopathological differences between groups of Internet users

Problematic Internet users had significantly higher scores in various psychopathological constructs as measured by BIS-53 compared with non-problematic Internet users (see Table 3).

Behavioral results

Differences in group performance. A 2 × 5 mixed ANOVA revealed a significant main effect of block [F(3.47,

Table 3. Psychopathological differences between non-problematic and problematic Internet users

	Non-problematic Internet users ($N = 45$)		Problematic Internet users ($N = 27$)			
	M	*SD*	*M*	*SD*	*t*(70)	*p*
BSI global severity index	0.58	0.45	1.11	0.62	−4.15	.001**
BSI positive symptom total	19.13	11.437	30.22	11.55	−3.96	.001**
BSI positive symptom distress index	1.42	0.46	1.82	0.48	−3.47	.001**
BSI somatization	0.32	0.41	0.65	0.57	−2.83	.006**
BSI obsession–compulsion	1.12	0.82	1.96	0.92	−4.02	.001**
BSI interpersonal sensitivity	0.76	0.73	1.34	0.97	−2.87	.005**
BSI depression	0.67	0.63	1.20	0.82	−3.04	.003**
BSI anxiety	0.49	0.51	0.95	0.70	−3.15	.002**
BSI hostility	0.48	0.52	0.83	0.69	−2.44	.017*
BSI phobic anxiety	0.26	0.45	0.71	0.81	−2.98	.004**
BSI paranoid ideation	0.64	0.76	1.09	0.85	−2.30	.024*
BSI psychoticism	0.56	0.61	1.13	0.84	−3.29	.002**

Note. BSI = Brief Symptom Inventory.
*$p < .05$, **$p < .01$, statistically significant (two-tailed).

242.89) = 6.93, $p = .001$, $\eta_p^2 = 0.09$; the Greenhouse–Geisser correction was used because the assumption of sphericity was violated], and significant interaction between block and groups of Internet users [$F(3.47, 242.89) = 3.12$, $p = .006$, $\eta_p^2 = 0.05$; Greenhouse–Geisser correction] indicated that the two groups differed in their performance on the IGT at certain times within the task. However, the overall difference between groups of Internet users did not reach significance [$F(1, 70) = 1.74$, $p = .19$, $\eta_p^2 = 0.02$]. Post-hoc tests using Bonferroni correction revealed that the between-groups differences in relation to IGT performance were significant for the second block of trials [$t(70) = 2.62$, $p = .01$, 95% confidence interval (CI) [1.08, 8.01], $d = 0.62$]. Additionally, non-problematic Internet users showed a significant preference for advantageous decks from the first block to the second block [$t(44) = -4.18$; $p = .011$, 95% CI [−8.69, −3.04], $d = 0.58$] and continued with a similar strategy, as no further significant differences in their performance between blocks were found. For the problematic Internet users, improvement in performance occurred in the fifth block [$t(26) = -3.77$; $p = .005$, 95% CI [−12.25, −3.60], $d = 0.57$]. Even though these data imply that the problematic Internet users have slower learning rates, there were no overall differences in task performance between the groups of Internet users (Figure 1).

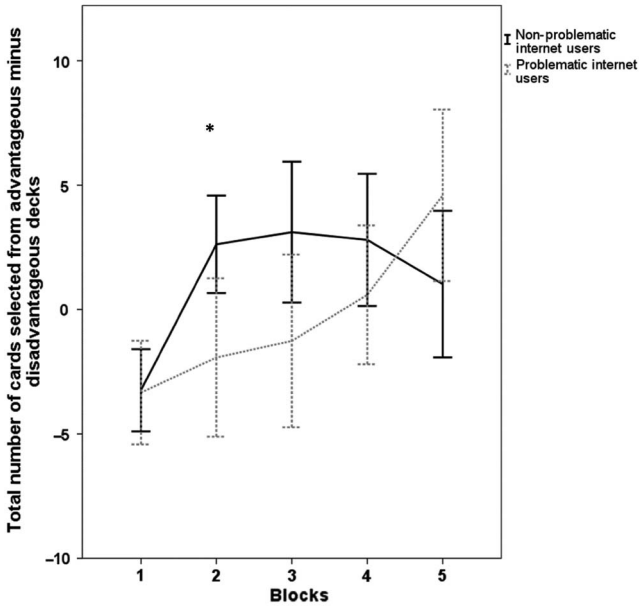

Figure 1. Performance on IGT for each block for non-problematic and problematic Internet users and CI error bars, *$p < .05$

Skin conductance result

Group differences in SCRs. The problematic Internet users had significantly stronger SCRs when they received a punishment from disadvantageous decks compared with non-problematic Internet users ($U = 494$, $Z = 2.5$, $p = .01$, $r = .34$; Figure 2). This was the only significant difference between the groups of Internet users ($p > .05$).

Finally, researching the differences between advantageous and disadvantageous decks for each type of SCRs (reward, punishment, and anticipatory) related to each Internet user group revealed that only non-problematic Internet users had stronger SCRs when they received a reward from advantageous compared with disadvantageous decks ($W = 440$, $Z = 2.44$, $p = .01$, $r = .42$; Figure 2). There were no other significant differences ($p > .05$) related to punishment or anticipatory SCRs between the two types of deck for each group of Internet users.

DISCUSSION

Problematic Internet users did not show the expected impaired performance on the IGT compared with non-problematic Internet users. The only difference between the groups of Internet users was early in the task, where non-problematic Internet users showed an early shift in their performance toward advantageous decks, whereas problematic Internet users showed a slower and more gradual shift in

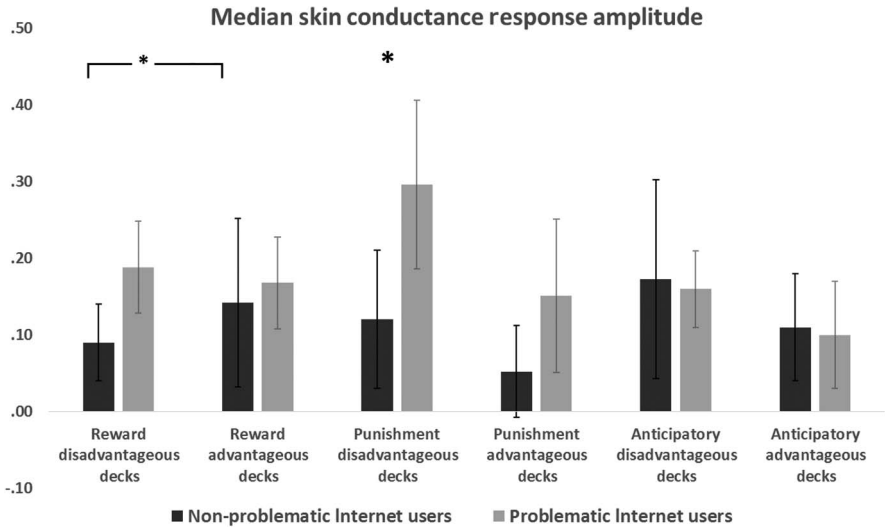

Figure 2. SCRs for non-problematic Internet users (left bars) and problematic Internet users (right bars) after they received reward, punishment, and in anticipation of these for advantageous and disadvantageous decks on the IGT with CI error bars, $*p < .05$

their performance. The main hypothesis that choice biases prevalent in addiction (Goudriaan et al., 2006; Verdejo-Garcia et al., 2007) are also apparent in PIU is not supported by the current findings.

This study was the first to assess SCRs during performance on the IGT in non-problematic and problematic Internet users. A main finding was that the problematic Internet users expressed stronger SCRs after receiving punishments from disadvantageous decks, which were associated with higher magnitude of punishment, denoting increased levels of sensitivity to negative feedback compared with non-problematic Internet users. This contrasts with literature on addiction where increased sensitivity to reward and decreased sensitivity to punishment is evident (Bechara et al., 2002; Goudriaan et al., 2006), implying that not only are there behavioral differences but the biases in underlying biological mechanisms also differ between them. Additionally, both groups of Internet users showed intact SMs (anticipatory SCRs). This comes in contrast to the addiction literature where addicted individuals showed blunted SMs activation (Bechara & Damasio, 2002; Bechara et al., 2002; Goudriaan et al., 2006). Given that problematic Internet users showed an increased physiological response to punishment suggests that they are significantly more risk-sensitive. Considering that our sample might be associated with symptomatic behavior of PIU, further research needs to investigate whether sensitivity to punishment is a stable marker of PIU.

Similar to the findings from this study, other research has also demonstrated elevated levels of sensitivity to punishment in problematic Internet users (Meerkerk, van den Eijnden, Franken, & Garretsen, 2010). Moreover, personality traits, as well as psychological states, in which sensitivity to negative feedback is a component such as anxiety, neuroticism, and psychoticism, have also been implicated as vulnerability factors related to PIU (Cao, Sun, Wan, Hao, & Tao, 2011; De Leo & Wulfert, 2013; Li, Wang, & Wang, 2008; Lin, Ko, & Wu, 2011). However, the question still remains as to how sensitivity to punishment relates to PIU. Research from pathological gambling has found differences in the motivation to gamble in a subgroup of gamblers, slot machine gamblers, who have elevated levels of sensitivity to punishment (Goudriaan et al., 2005). It has been argued that their primary motivation for gambling was to escape the stresses of everyday life, which is in opposition to the reward-seeking motivation normally associated with gambling (Blaszczynski & Nower, 2002; Ledgerwood & Petry, 2006). Thus, it can be suggested that in situations with increased chances of adverse outcomes, some individuals with elevated levels of sensitivity to punishment might engage in approach behavior to ameliorate adverse experiences. In a similar way, it can be argued there is a possibility that some individuals with elevated levels of sensitivity to punishment might engage with online activities to escape negative stressful situations found in everyday life. Support for such an assumption comes from studies that have found strong links between social anxiety and PIU (Caplan, 2007; Clayton, Osborne, Miller, & Oberle, 2013; De Leo & Wulfert, 2013). Socially anxious individuals perceive face-to-face interactions as highly unfavorable, whereas they typically perceive the online environment as a safe place for social interaction due to the lack of physical face-to-face encounters (Campbell, Cumming, & Hughes, 2006). Thus, this preference for online interaction might make them more vulnerable to develop PIU. In this study, problematic Internet users had higher levels of various anxiety-related psychopathological constructs compared with non-problematic Internet users, providing further support for our conclusion. This argument can be further validated citing research, which demonstrates that using the Internet for socializing (chat rooms, instant messenger, etc.) is one of the activities that is highly correlated with PIU (Kuss & Griffiths, 2011), which was further validated in this study. Thus, it seems that motivational mechanisms associated with the pursuit of online activities, which are based on punishment aversion, appear to be different from the ones associated with drug-seeking behavior that is reward-seeking behavior.

Additionally, the aforementioned argument can account for the differences between this and Ko et al.'s (2010) and Sun et al.'s (2009) studies. In Ko et al.'s (2010) and Sun et al.'s (2009) studies, problematic Internet users consisted of gamers, whereas in this study, PIU was associated mostly with more generic online applications and specific related to social networking. It was argued that Internet users might choose online interaction as a means to overcome their anxieties. However, this might differ for gamers who might choose to game for satisfaction and excitement. The motivational differences underlying online behavior could be one of the reasons for discrepancies between studies. Future research should investigate whether potential different subtypes of PIU differ in their motives underlying online behavior.

In conclusion, the results from this study reveal that there are differences in biased choice functioning between PIU and other addictions, as well as in the biological function underpinning these biases. This study has identified targets for future research. Furthermore, this study suggests that sensitivity to punishment should be incorporated into in any measure and, potentially, any intervention for PIU.

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Authors' contribution: All authors were responsible for the study design. MN was responsible for the collection and analysis of the data. MN drafted the manuscript. NH and DSF assisted in the critical revision of this manuscript for important intellectual content. All authors critically reviewed the content and approved the final version of this paper for publication.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

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

Bechara, A., & Damasio, H. (2002). Decision-making and addiction (part I): Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequence. *Neuropsychologia, 40*(10), 1675–1689. doi:10.1016/S0028-3932(02)00015-5

Bechara, A., Damasio, H., Damasio, A. R., & Lee, G. P. (1999). Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *The Journal of Neuroscience, 19*(13), 5473–5481.

Bechara, A., Dolan, S., & Hindes, A. (2002). Decision-making and addiction (part II): Myopia for the future or hypersensitivity to reward? *Neuropsychologia, 40*(10), 1690–1705. doi:10.1016/S0028-3932(02)00016-7

Blaszczynski, A., & Nower, L. (2002). A pathways model of problem and pathological gambling. *Addiction, 97,* 487–499. doi:10.1046/j.1360-0443.2002.00015.x

Brand, M., Kalbe, E., Labudda, K., Fujiwara, E., Kessler, J., & Markowitsch, H. J. (2005). Decision-making impairments in patients with pathological gambling. *Psychiatry Research, 133,* 91–99. doi:10.1016/j.psychres.2004.10.003

Brown, R. I. F. (1991). Gaming, gambling and other addictive play. In J. H. Kerr & M. J. Apter (Eds.), *Adult play: A reversal theory approach* (pp. 101–118). Amsterdam: Swets & Zeitlinger.

Brown, R. I. F. (1993). Some contributions of the study of gambling to the study of other addictions. In W. R. Eadington & J. A. Cornelius (Eds.), *Gambling behavior and problem gambling* (pp. 241–272). Reno, NV: University of Nevada.

Campbell, A. J., Cumming, S. R., & Hughes, I. (2006). Internet use by the socially fearful: Addiction or therapy? *CyberPsychology & Behavior, 9*(1), 69–81. doi:10.1089/cpb.2006.9.69

Cao, H., Sun, Y., Wan, Y., Hao, J., & Tao, F. (2011). Problematic Internet use in Chinese adolescents and its relation to psychosomatic symptoms and life satisfaction. *BMC Public Health, 11*(1), 802. doi:10.1186/1471-2458-11-802

Caplan, S. E. (2007). Relations among loneliness, social anxiety, and problematic Internet use. *CyberPsychology & Behavior, 10*(2), 234–242. doi:10.1089/cpb.2006.9963

Clayton, R. B., Osborne, R. E., Miller, B. K., & Oberle, C. D. (2013). Loneliness, anxiousness, and substance use as predictors of Facebook use. *Computers in Human Behavior, 29*(3), 687–693. doi:10.1016/j.chb.2012.12.002

Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: Grosset/Putnam.

Davis, R. A. (2001). A cognitive-behavioral model of pathological Internet use. *Computers in Human Behavior, 17,* 187–195. doi:10.1016/S0747-5632(00)00041-8

De Leo, J. A., & Wulfert, E. (2013). Problematic Internet use and other risky behaviors in college students: An application of problem-behavior theory. *Psychology of Addictive Behaviors, 27*(1), 133–141. doi:10.1037/a0030823

Demetrovics, Z., Szeredi, B., & Rozsa, S. (2008). The three-factor model of Internet addiction: The development of the Problematic Internet Use Questionnaire. *Behavior Research Methods, 40*(2), 563–574. doi:10.3758/BRM.40.2.563

Derogatis, L. R. (1993). *BSI–Brief Symptom Inventory: Administration, scoring, and procedure manual* (4th ed.). Minneapolis, MN: National Computer Systems.

Derogatis, L. R., & Melisaratos, N. (1983). The Brief Symptom Inventory: An introductory report. *Psychological Medicine, 13,* 595–605. doi:10.1017/S0033291700048017

Dong, G., & Zhou, H. (2010). Is impulse-control ability impaired in people with Internet addiction disorder: Electrophysiological evidence from ERP studies. *International Journal of Psychophysiology, 77*(3), 334–335. doi:10.1016/j.ijpsycho.2010.06.271

DuPont, R. L. (1995). Anxiety and addiction: A clinical perspective on comorbidity. *Bulletin of the Menninger Clinic, 59*(2), A53–A72.

Eijnden, R. J. J. M., Meerkerk, G. J., Vermulst, A., Spijkerman, R., & Engels, R. C. E. (2008). Online communication, compulsive Internet use, and psychosocial well-being among adolescents: A longitudinal study. *Developmental Psychology, 44*(3), 655–665. doi:10.1037/0012-1649.44.3.655

Goudriaan, A. E., Oosterlaan, J., de Beurs, E., & van den Brink, W. (2005). Decision making in pathological gambling: A comparison between pathological gamblers, alcohol dependents, persons with Tourette syndrome, and normal controls. *Cognitive Brain Research, 23,* 137–151. doi:10.1016/j.cogbrainres.2005.01.017

Goudriaan, A. E., Oosterlaan, J., de Beurs, E., & van den Brink, W. (2006). Psychophysiological determinants and concomitants of deficient decision making in pathological gamblers. *Drug and Alcohol Dependence, 84,* 231–239. doi:10.1016/j.drugalcdep.2006.02.007

Grant, J. E., Potenza, M. N., Weinstein, A., & Gorelick, D. A. (2010). Introduction to behavioral addictions. *The American Journal of Drug and Alcohol Abuse, 36*(5), 233–241. doi:10.3109/00952990.2010.491884

Griffiths, M. D. (1999). Internet addiction: Fact or fiction? The Psychologist. *British Psychological Society, 12*, 246–250.

Griffiths, M. D. (2000). Internet addiction – Time to be taken seriously? *Addiction Research, 8*(5): 413–418. doi:10.3109/16066350009005587

Johnson, B. (2009). Depression and addiction. In T. L. Schwartz & T. J. Petersen (Eds.), *Depression: Treatment strategies and management* (2nd ed.). New York: Taylor & Francis.

Ko, C. H., Hsiao, S., Liu, G. C., Yen, J. Y., Yang, M. J., & Yen, C. F. (2010). The characteristics of decision making, potential to take risks, and personality of college students with Internet addiction. *Psychiatry Research, 175*(1–2), 121–125. doi:10.1016/j.psychres.2008.10.004

Kuss, D. J., & Griffiths, M. D. (2011). Online social networking and addiction – A review of the psychological literature. *International Journal of Environmental Research and Public Health, 8*(9), 3528–3552. doi:10.3390/ijerph8093528

Ledgerwood, D. M., & Petry, N. M. (2006). Psychological experience of gambling and subtypes of pathological gamblers. *Psychiatry Research, 144*(1), 17–27. doi:10.1016/j.psychres.2005.08.017

Li, H., Wang, J., & Wang, L. (2008). A survey on the generalized problematic Internet use in Chinese college students and its relations to stressful life events and coping style. *International Journal of Mental Health and Addiction, 7*(2), 333–346. doi:10.1007/s11469-008-9162-4

Lin, M. P., Ko, H. C., & Wu, J. Y. (2011). Prevalence and psychosocial risk factors associated with Internet addiction in a nationally representative sample of college students in Taiwan. *Cyberpsychology, Behavior, and Social Networking, 14*(12), 741–746. doi:10.1089/cyber.2010.0574

Meerkerk, G. J., van den Eijnden, R. J. J. M., Franken, I. H. A., & Garretsen, H. F. L. (2010). Is compulsive Internet use related to sensitivity to reward and punishment, and impulsivity? *Computers in Human Behavior, 26*(4), 729–735. doi:10.1016/j.chb.2010.01.009

Moore, T. H. M., Zammit, S., Lingford-Hughes, A., Barnes, T. R. E., Jones, P. B., Burke, M., & Lewis, G. (2007). Cannabis use and risk of psychotic or affective mental health outcomes: A systematic review. *The Lancet, 370*(9584), 319–328. doi:10.3410/f.1089285.542491

Office for National Statistics. (2014). *Internet Access – Households and Individuals 2014*. Retrieved from http://www.ons.gov.uk/ons/rel/rdit2/internet-access—households-and-individuals/2014/stb-ia-2014.html

Shaffer, H. J., LaPlante, D. A., LaBrie, R. A., Kidman, R. C., Donato, A. N., & Stanton, M. V. (2004). Toward a syndrome model of addiction: Multiple expressions, common etiology. *Harvard Review of Psychiatry, 12,* 367–374. doi: 10.1080/10673220490905705

Stern, S. E. (1999). Addiction to technologies: A social psychological perspective of Internet addiction. *CyberPsychology & Behavior, 2*(5), 419–424. doi:10.1089/cpb.1999.2.419

Sun, D. L., Chen, Z. J., Ma, N., Zhang, X. C., Fu, X. M., & Zhang, D. R. (2009). Decision-making and prepotent response inhibition functions in excessive Internet users. *CNS Spectrums, 14,* 75–81. doi: 10.1017/S1092852900000225

Van Rooij, A. J. (2011). *Online video game addiction. Exploring a new phenomenon* (PhD thesis). Erasmus University Rotterdam, The Netherlands.

Verdejo-García, A., & Bechara, A. (2009). A somatic marker theory of addiction. *Neuropharmacology, 56,* 48–62. doi:10.1016/j.neuropharm.2008.07.035

Verdejo-Garcia, A., Benbrook, A., Funderburk, F., David, P, Cadet, J. L., & Bolla, K. I. (2007). The differential relationship between cocaine use and marijuana use on decision-making performance over repeat testing with the Iowa Gambling Task. *Drug and Alcohol Dependence, 90*(1), 2–11. doi:10.1016/j.drugalcdep.2007.02.004

Villella, C., Martinotti, G., Di Nicola, M., Cassano, M., La Torre, G., Gliubizzi, M. D., Messeri, I., Petruccelli, F., Bria, P., Janiri, L., & Conte, G. (2010). Behavioural addictions in adolescents and young adults: Results from a prevalence study. *Journal of Gambling Studies, 27*(2), 203–214. doi:10.1007/s10899-010-9206-0

Yellowlees, P. M., & Marks, S. (2007). Problematic Internet use or Internet addiction? *Computers in Human Behavior, 23*(3), 1447–1453. doi:10.1016/j.chb.2005.05.004

Yen, J. Y., Ko, C. H., Yen, C. F., Chen, S. H., Chung, W. L., & Chen, C. C. (2008). Psychiatric symptoms in adolescents with Internet addiction: Comparison with substance use. *Psychiatry and Clinical Neurosciences, 62*(1), 9–16. doi:10.1111/pcn.2008.62.issue-1

Yen, J. Y., Yen, C. F., Chen, C. C., Chen, S. H., & Ko, C. H. (2007). Family factors of Internet addiction and substance use experience in Taiwanese adolescents. *CyberPsychology & Behavior, 10*(3), 323–329. doi:10.1089/cpb.2006.9948

Young, K. S. (1999). Internet addiction: Symptoms, evaluation and treatment. In L. VandeCreek & T. Jackson (Eds.), *Internet addiction: A source book* (pp. 19–31). Sarasota, FL: Professional Resource Press.

Yuan, K., Qin, W., Wang, G., Zeng, F., Zhao, L., Yang, X., Liu, P., Liu, J., Sun, J., von Deneen, K. M., Gong, Q., Liu, Y., & Tian, J. (2011). Microstructure abnormalities in adolescents with Internet addiction disorder. *PLoS ONE, 6*(6), e20708. doi:10.1371/journal.pone.0020708