Addiction

RESEARCH REPORT

doi:10.1111/add.12494

Strategic and non-strategic problem gamblers differ on decision-making under risk and ambiguity

Felicity K. Lorains[1], Nicki A. Dowling[1,2,3], Peter G. Enticott[2,4], John L. Bradshaw[1], Jennifer S. Trueblood[5] & Julie C. Stout[1]

School of Psychological Sciences, Monash University, Clayton, Vic., Australia,[1] School of Psychology, Deakin University, Burwood, Vic., Australia,[2] Problem Gambling Research and Treatment Centre, The University of Melbourne, Melbourne, Vic., Australia,[3] Monash Alfred Psychiatry Research Centre, The Alfred and Central Clinical School, Monash University, Melbourne, Vic., Australia[4] and Department of Cognitive Sciences, University of California, Irvine, CA, USA[5]

ABSTRACT

Aims To analyse problem gamblers' decision-making under conditions of risk and ambiguity, investigate underlying psychological factors associated with their choice behaviour and examine whether decision-making differed in strategic (e.g. sports betting) and non-strategic (e.g. electronic gaming machine) problem gamblers. **Design** Cross-sectional study. **Setting** Out-patient treatment centres and university testing facilities in Victoria, Australia. **Participants** Thirty-nine problem gamblers and 41 age, gender and estimated IQ-matched controls. **Measurements** Decision-making tasks included the Iowa Gambling Task (IGT) and a loss aversion task. The Prospect Valence Learning (PVL) model was used to provide an explanation of cognitive, motivational and response style factors involved in IGT performance. **Findings** Overall, problem gamblers performed more poorly than controls on both the IGT ($P = 0.04$) and the loss aversion task ($P = 0.01$), and their IGT decisions were associated with heightened attention to gains ($P = 0.003$) and less consistency ($P = 0.002$). Strategic problem gamblers did not differ from matched controls on either decision-making task, but non-strategic problem gamblers performed worse on both the IGT ($P = 0.006$) and the loss aversion task ($P = 0.02$). Furthermore, we found differences in the PVL model parameters underlying strategic and non-strategic problem gamblers' choices on the IGT. **Conclusions** Problem gamblers demonstrated poor decision-making under conditions of risk and ambiguity. Strategic (e.g. sports betting, poker) and non-strategic (e.g. electronic gaming machines) problem gamblers differed in decision-making and the underlying psychological processes associated with their decisions.

Keywords Ambiguity, decision-making, loss aversion, problem gambling, reward processing, risk-taking.

Correspondence to: Julie C. Stout, Building 17, School of Psychological Sciences, Monash University, Clayton, Vic. 3800, Australia.
E-mail: Julie.Stout@monash.edu.au

Submitted 25 June 2013; initial review completed 13 October 2013; final version accepted 14 January 2014

INTRODUCTION

Problem gambling is being viewed increasingly as a behavioural addiction and has been re-classified as an addictive disorder in the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5) [1]. Decision-making is a critical cognitive process involved in addictive disorders [2], and both substance abusers and problem gamblers demonstrate decision-making impairments. Like substance abuse, problem gambling may be, in part, a decision-making disorder [3], and laboratory-based decision-making studies are providing useful insights into problem gambling.

Decision-making studies have shown that problem gamblers perform more poorly than controls under risk and ambiguity. On the Iowa Gambling Task (IGT), a commonly used decision-making task, problem gamblers make significantly more disadvantageous choices and are slower to learn from feedback than controls [4–6]. On other decision-making tasks, problem gamblers are more impulsive [7,8], overconfident [9] and take less time to deliberate [4], and even when explicit risk information is available choose risky and disadvantageous options [10–12]. Problem gamblers also display poor knowledge of probabilities, which is associated strongly with gambling behaviour [13], and evidence suggests that decision-making under ambiguity, but not under risk, is associated with increased problem gambling severity [11].

Advances in decision-making research have allowed for more precise and mechanistic investigations into cognitive processes driving decision-making. For example, our group has developed cognitive models (the Expectance Valence Learning model [14] and the Prospect Valence Learning (PVL) model [15]) that allow IGT performance to be decomposed into constituent psychological processes. These models have demonstrated different combinations of cognitive, motivational and response style factors in the decision-making of cocaine and polysubstance abusers, Huntington's disease and individuals with orbitofrontal brain lesions [16]. Cognitive modelling has not been applied previously to problem gamblers.

Another key factor involved in decision-making that may be relevant to problem gambling is loss aversion. Loss aversion refers to a phenomenon in which people demonstrate greater sensitivity to losses than gains during decision-making [17], and may result from an asymmetry in affective responses in which negative and positive stimuli are not equally weighted [18]. Loss aversion is associated with emotional processing [19,20], and the absence of loss aversion could reflect an inability to integrate or differentially process affective information [21]. Problem gamblers demonstrate altered neural representations of losses [22,23] and emotional signalling deficits during decision-making according to the 'somatic marker hypothesis' [24]. Therefore, investigating problem gamblers' loss aversion may provide key insights into their decision-making.

Decision-making alterations may relate differentially to gambling type. Problem gambling is a heterogeneous disorder [25–27], and many problem gamblers report a specific gambling form as most problematic [28]. Compared to problem gamblers who prefer strategic gambling (e.g. sports betting, poker), problem gamblers who prefer non-strategic gambling (e.g. electronic gaming machines: EGMs) are more likely to be older and female [29], demonstrate greater gambling severity [30] and have a faster onset of problem gambling [31]. Furthermore, EGM problem gamblers have displayed poorer IGT performance and a more conservative approach on the Card Playing Task than casino problem gamblers [4]. Importantly, gender needs to be considered when subgrouping problem gamblers based on preferred gambling form, as non-strategic gamblers tend to be women and strategic gamblers tend to be men [29,32]. Past research suggests that women perform more poorly on the IGT [33,34] and are more sensitive to losses than men [35].

In this study, we investigated factors associated with problem gamblers' decision-making under conditions of risk and ambiguity, and examined differences in decision-making between problem gambling subtypes. Specifically, we applied a cognitive modelling procedure to examine the cognitive, motivational and response style processes underlying problem gamblers' IGT performances, and investigated problem gamblers' sensitivity to losses on a loss aversion task. We hypothesized that problem gamblers would perform more poorly than controls on both the IGT and a loss aversion task. Additionally, we examined whether preferring strategic or non-strategic gambling activities was associated differentially with decision-making using gender-matched controls. We hypothesized that non-strategic problem gamblers would perform more poorly on both decision-making tasks than their gender-matched controls, while strategic problem gamblers might not differ from their gender-matched controls.

METHOD

Participants and procedures

Thirty-nine problem gamblers were recruited through Gamblers Help, an out-patient counselling service in Victoria, Australia. Problem gamblers met diagnostic criteria for problem gambling (≥8) on the Problem Gambling Severity Index (PGSI) from the Canadian Problem Gambling Index [36]. In addition, 41 community recruited controls were matched to the problem gamblers on age, gender and estimated IQ. IQ was estimated using the National Adult Reading Test [37], a reliable and valid measure of pre-morbid IQ [38–40]. We based our sample size on past research [4] suggesting a large difference ($\eta^2 = 0.12$) between problem gamblers and controls on the IGT, and the anticipated statistical power of the study was 0.8. Exclusion criteria included age over 65 years, previous head injury, neurological disorders, psychosis/psychotic disorders and recent alcohol or illicit drug use (previous 12 hours). Additional exclusion criteria for controls included current or life-time mental health disorders [measured by the Mini-International Neuropsychiatric Interview (MINI) [41]], greater than three on the PGSI, and gambling more than monthly. The groups did not differ on age or estimated IQ; however, controls reported higher years of education (see Table 1). Problem gamblers scored higher on psychological distress as measured by the Depression Anxiety and Stress Scale (DASS) [42]; however, we found no difference in alcohol use and related problems on the Alcohol Use Disorders Identification Test [43]. Due to the high prevalence of comorbid disorders in problem gambling [44], problem gamblers with comorbidities were included in our sample (Table 1).

Participants were allocated into strategic and non-strategic gambling forms based on Grant and colleagues'

Table 1 Means and standard deviations (in parentheses) for demographic and clinical data.

	PGs *n* = 39	*Control* *n* = 41	*Test statistic*
Gender (M/F)	19/20	21/20	
Age (years)	46.64 (9.46)	44.34 (11.43)	$t_{(77)} = -0.98$, NS
Years of education	12.88 (2.09)	14.76 (2.28)	$t_{(78)} = 3.82$, $P < 0.001$
Estimated IQ (NART)	103.54 (6.99)	106.87 (9.44)	$t_{(78)} = 1.81$, NS
Gambling severity (PGSI)	18.31 (4.79)	0.27 (0.71)	$t_{(40)} = -23.27$, $P < 0.001$
Self-reported years of PG	14.92 (9.61)		
DASS—depression	15.59 (12.42)	3.41 (3.56)	$t_{(44)} = -5.90$, $P < 0.001$
DASS—anxiety	11.85 (11.35)	1.37 (1.86)	$t_{(40)} = -5.83$, $P < 0.001$
DASS—stress	17.90 (11.71)	5.66 (4.19)	$t_{(47)} = -6.16$, $P < 0.001$
DASS—total	45.95 (33.91)	10.44 (7.73)	$t_{(42)} = -6.39$, $P < 0.001$
AUDIT total	5.32 (6.16)	4.56 (4.21)	$t_{(65)} = -0.63$, NS
DSM-IV comorbid disorders			
Major depressive episode	8 (20.5%)		
Major depressive disorder	10 (25.6%)		
Dysthymia	7 (17.9%)		
Hypomanic episode—past	3 (7.7%)		
Manic episode—past	5 (12.8%)		
Panic disorder	3 (7.7%)		
Panic disorder life-time	10 (25.6%)		
Agoraphobia	3 (7.7%)		
Social phobia	1 (2.6%)		
Post-traumatic stress disorder	1 (2.6%)		
Alcohol dependence	2 (5.1%)		
Alcohol abuse	1 (2.6%)		
Substance dependence	3 (7.7%)		
Substance abuse	1 (2.6%)		
Generalized anxiety disorder	2 (5.1%)		
Antisocial personality disorder—life-time	4 (10.3%)		
Any comorbid disorder	30 (76.9%)		

All scores are mean (standard deviation) unless otherwise indicated. All comorbid disorders are current unless stated otherwise. Group demographics and clinical variables were compared using two-tailed independent *t*-tests and corrected for multiple comparisons using Bonferroni's correction method. PGs = problem gamblers; M = male, F = female; NART = National Adult Reading Test; PGSI = Problem Gambling Severity Index; DASS = Depression, Anxiety and Stress Scale; AUDIT = Alcohol Use Disorders Identification Test; NS = not significant.

[30] criteria for most problematic gambling form. Strategic gambling included games where skill or knowledge may have some impact on the outcome (e.g. poker, sports betting, horse/dog races), while non-strategic gambling included games of chance that involve little or no skill (e.g. EGMs, bingo) [30]. No problem gamblers reported equal preference for both forms. A large gender difference was present in the gambling subtypes, with only male strategic problem gamblers ($n = 15$) and more female non-strategic problem gamblers ($n = 24$). As the gambling subtypes differed on more than one attribute (gender and gambling form), we compared the gambling subtypes to age, gender and estimated IQ-matched control groups. Strategic and non-strategic problem gamblers did not differ on age, education, estimated IQ, psychological distress or alcohol use (Table 2). However, non-strategic problem gamblers reported greater gambling severity and fewer years of problem gambling than strategic problem gamblers.

Participants provided signed informed consent and the study protocol was approved by the Monash University Human Research Ethics Committee and the Department of Justice (Victoria) Research Ethics Committee. Participants were tested individually in a quiet room as part of a larger study with the order of tasks fixed. Participants were reimbursed with a gift voucher to a local department store.

Measures

Iowa Gambling Task (IGT)

We used a computerized IGT based on Bechara *et al.* [45]. Participants were presented with four card decks and instructed to accumulate as much (play) money as possible by choosing cards from the decks. Decks differed in payoffs and penalties. Selections from decks A and B yielded \$100 and decks C and D yielded \$50, with winnings often paired with a loss. Decks A and B were

Table 2 Demographic and clinical data for problem gamblers based on preferred gambling form.

	Strategic PGs *n* = 15	*Non-strategic PGs* *n* = 24	*Test statistic*
Gender (M/F)	15/0	4/19	
Age	44.33 (8.12)	48.08 (10.10)	$t_{(37)} = -1.21$, NS
Years of education	12.67 (2.61)	13.02 (1.75)	$t_{(37)} = -0.51$, NS
Estimated IQ (NART)	102.13 (8.68)	104.42 (5.72)	$t_{(22)} = -0.99$, NS
Gambling severity (PGSI)	15.40 (4.75)	20.13 (3.90)	$t_{(37)} = -3.38$, $P < 0.01$
Self-reported years of PG	20.73 (11.95)	11.29 (5.48)	$t_{(18)} = 2.88$, $P < 0.01$
DASS—depression	12.93 (12.98)	17.25 (12.04)	$t_{(37)} = -1.06$, NS
DASS—anxiety	10.53 (11.48)	12.67 (11.43)	$t_{(37)} = -0.57$, NS
DASS—stress	14.67 (12.46)	19.92 (10.99)	$t_{(37)} = -1.38$, NS
DASS—total	38.13 (34.61)	51.22 (33.94)	$t_{(37)} = -1.14$, NS
AUDIT Ttotal	5.67 (6.51)	5.09 (6.06)	$t_{(37)} = 0.28$, NS
DSM-IV comorbid disorders			
Major depressive episode	4 (26.7%)	4 (16.7%)	
Major depressive disorder	3 (20.0%)	7 (29.2%)	
Dysthymia	0	7 (29.2%)	
Hypomanic episode—past	1 (6.7%)	2 (8.3%)	
Manic episode—past	1 (6.7%)	4 (16.7%)	
Panic disorder	1 (6.7%)	2 (8.3%)	
Panic disorder life-time	4 (26.7%)	6 (25.0%)	
Agoraphobia	1 (6.7%)	2 (8.7%)	
Social phobia	1 (6.7%)	0	
Post-traumatic stress disorder	0	1 (4.3%)	
Alcohol dependence	0	2 (8.3%)	
Alcohol abuse	1 (6.7%)	0	
Substance dependence	1 (6.7%)	2 (8.3%)	
Substance abuse	1 (6.7%)	0	
Generalized anxiety disorder	0	2 (8.7%)	
Antisocial personality disorder—life-time	1 (6.7%)	3 (13%)	
Any comorbid disorder	9 (60.0%)	21 (87.5%)	

All scores are mean (standard deviation) unless otherwise indicated. Group demographics and clinical variables were compared using two-tailed independent *t*-tests and corrected for multiple comparisons using Bonferroni's correction method. PGs = problem gamblers; strategic PGs = sports-betting (*n* = 12) and casino games (*n* = 3); non-strategic = EGMs (*n* = 24); M = male, F = female; NART = National Adult Reading Test; PGSI = Problem Gambling Severity Index; DASS = Depression, Anxiety and Stress Scale; AUDIT = Alcohol Use Disorders Identification Test; NS = not significant.

disadvantageous because the occasional losses ($150–$1250) resulted in losing $250 per 10 cards. Decks C and D were advantageous because the occasional losses ($25–$250) resulted in a net gain of $250 per 10 cards. The deck positions were assigned randomly and all participants began with $2000. The task consisted of 150 trials in 6 blocks of 25 trials, with feedback (net win/loss) provided after each block. Instructions were based on Bechara *et al*. [46]. Task performance was measured by the net score [advantageous choices (C + D) minus disadvantageous choices (A + B)] in each block.

PVL model for decomposing IGT performance [15]

The PVL model was used to disentangle underlying psychological processes involved in IGT performance (see Supporting information, Appendix S1). The PVL model yields four free parameters: utility shape, loss aversion, recency/learning and consistency. The utility shape parameter measures the attention given to the magnitude of gains. The loss aversion parameter indicates sensitivity to losses. The recency/learning parameter indicates attention given to past experiences with a deck versus attention given to the most recent deck selection. Lastly, the consistency parameter measures how consistent the decision-makers' selections are with their expected value. For example, chronic cannabis users' IGT choices are associated with less sensitivity to losses, more sensitivity to increases in gains, more attention to recent outcomes and less consistency [47], whereas patients with Huntington's disease display more attention to recent outcomes and greater attention to gains during IGT choices [14].

Loss aversion task

The loss aversion task was based on the De Martino *et al*. [48] task and administered using E-Prime (version 2.0).

Table 3 Mean and standard deviations (SD) (in parentheses) of the model parameters for the Prospect Valence Learning (PVL) model and the Bayesian information criterion (BIC) scores.

	PGs *Mean (SD)*	*Control* *Mean (SD)*	*Test statistic*
Overall sample			
Utility shape*	0.32 (0.13)	0.25 (0.12)	$F_{(1,77)} = 9.44$, $P = 0.003$, $\eta^2 = 0.11$
Loss aversion	0.86 (0.68)	0.75 (0.51)	$F_{(1,77)} = 0.66$, NS
Recency/learning	0.65 (0.24)	0.66 (0.24)	$F_{(1,77)} = 0.25$, NS
Consistency**	0.18 (0.07)	0.29 (0.16)	$F_{(1,77)} = 9.80$, $P = 0.002$, $\eta^2 = 0.11$
BIC	17.02 (24.21)	22.67 (27.90)	–
Strategic groups			
Utility shape**	0.45 (0.17)	0.23 (0.14)	$F_{(1,29)} = 16.02$, $P = 0.0004$, $\eta^2 = 0.36$
Loss aversion**	1.01 (0.54)	0.37 (0.15)	$F_{(1,29)} = 11.09$, $P = 0.002$, $\eta^2 = 0.28$
Recency/learning	0.75 (0.27)	0.71 (0.18)	$F_{(1,29)} = 0.23$, NS
Consistency**	0.13 (0.05)	0.32 (0.16)	$F_{(1,29)} = 16.48$, $P = 0.\ 0003$, $\eta^2 = 0.36$
BIC	14.01 (22.76)	20.58 (33.36)	–
Non-strategic groups			
Utility shape	0.23 (0.04)	0.23 (0.08)	$F_{(1,\ 45)} = 0.85$, NS
Loss aversion**	0.20 (0.17)	1.01 (0.72)	$F_{(1,45)} = 17.48$, $P = 0.0001$, $\eta^2 = 0.28$
Recency/learning	0.55 (0.22)	0.63 (0.28)	$F_{(1,45)} = 0.12$, NS
Consistency	0.27 (0.16)	0.30 (0.17)	$F_{(1,45)} = 0.01$, NS
BIC	16.29 (27.53)	18.35 (24.40)	–

Bayesian information criterion (BIC) scores were used to compare the PVL model to baseline statistical model with positive values indicating the PVL is a better model. For the PVL model parameters, groups were compared using an independent-samples *t*-test. Overall sample: PG ($n = 39$) and age, gender and estimated IQ-matched controls ($n = 41$); strategic groups: strategic PG ($n = 15$) and age, gender and estimated IQ-matched controls ($n = 17$); non-strategic groups: non-strategic PGs ($n = 24$) and age, gender and estimated IQ-matched controls ($n = 24$). *$P < 0.01$; **$P < 0.001$. PGs = problem gamblers.

Participants were instructed to accept or reject a series of mixed gambles with an equal probability (50%) of winning or losing a variable amount of money (e.g. win $25 or lose $5). Gambles were presented as a coin toss, and responses made by a key press. A five-trial practice-run was conducted first, then a single block of 49 trials. Wins ranged from $15 to $45 and losses ranged from $5 to $35, both in $5 increments. Because previous research suggests that people are twice as sensitive to losses as wins [18], the wins and losses were chosen to attempt to elicit a wide range of responses. The win/loss combination of each trial was determined randomly. Participants did not win or lose money based on performance; however, they were instructed to evaluate each gamble as if they would.

Gamble decision (yes or no) was recorded. Using the methods from Tom *et al*. [49], we computed an estimate of loss aversion (λ) for each participant by fitting a logistic regression to each participant's gamble decisions with the gain and loss as independent variables (see Supporting information, Appendix S1). This value indicates how heavily participants weighed losses compared to gains when deciding whether to accept a gamble.

Data analysis

The IGT was examined as six blocks of 25 trials. Research suggests that choices made during the first two blocks involve trial and error while participants attempt to learn the task [50]. Task performance then improves between the first and third blocks [51], and the later portion of the task indicates performance more clearly. Therefore, we analysed the first two blocks separately (learning trials) from the last four blocks (performance trials). To determine group and block effects, a repeated-measures analysis of covariance (ANCOVA) was conducted with group and gender as between-factors, block as within-factor and net score as the dependent measure. As depression and anxiety disorders were the most common comorbidities in our problem gamblers, we included the DASS total as a covariate. Mahalanobis distance indicated one multivariate outlier, which was excluded from analysis. Group differences in the PVL model parameters were analysed using a one-way ANCOVA with DASS total as a covariate. For all group analyses, the PVL model demonstrated a positive Bayesian information criterion, indicating that the PVL model provided a better fit than a baseline statistical model even after model complexity was considered (Table 3).

For the loss aversion task, we were unable to calculate loss aversion (λ) for eight participants (five problem gamblers and three controls) because they did not accept any gambles; thus these participants were excluded from analyses. However, according to Fisher's exact test, the ratio of non-responders did not differ between groups

($P = 0.47$). The remaining participants' loss aversion (λ) was compared using a one-way ANCOVA with group and gender as between-subject factors, and DASS total as a covariate.

RESULTS

Performance on the IGT

Across the learning trials there was no difference between problem gamblers and controls, with no main effect of group, $F_{(1,74)} = 0.05$, $P = 0.82$, block, $F_{(1,74)} = 0.30$, $P = 0.59$ and no group × block, $F_{(1,74)} = 0.44$, $P = 0.51$ or group × gender interaction, $F_{(1,74)} = 0.74$, $P = 0.39$. However, there was a main effect of gender, $F_{(1,74)} = 7.11$, $P = 0.009$, $\eta^2 = 0.09$, indicating that men performed better on the learning trials than women. On the performance trials, we found a main effect of group, $F_{(1,74)} = 4.41$, $P = 0.04$, $\eta^2 = 0.06$ and gender, $F_{(1,74)} = 26.35$, $P = 0.00002$, $\eta^2 = 0.26$, indicating that problem gamblers performed worse than controls, and men performed better than women. However, there was no main effect of block, $F_{(3,74)} = 0.57$, $P = 0.64$ and no group × block, $F_{(3,74)} = 0.70$, $P = 0.56$ or group × gender interaction, $F_{(1,74)} = 0.79$, $P = 0.39$. Both problem gamblers and controls demonstrated learning across the IGT, with more advantageous choices on the performance trials compared to the learning trials, $F_{(1,74)} = 7.44$, $P = 0.008$, $\eta^2 = 0.09$ (Fig. 1).

Using the PVL model we found that, compared to controls, problem gamblers were more influenced by the magnitude of the gains (higher utility shape), and their choices were more random or erratic (lower consistency). The groups did not differ on the recency/learning or loss aversion parameters (Table 3).

Strategic problem gamblers did not differ from controls on either the learning or performance trials of the IGT (Fig. 2). Specifically, on the learning trials, there was no main effect of group, $F_{(1,29)} = 0.33$, $P = 0.57$ or block, $F_{(1,29)} = 0.63$, $P = 0.43$ and no group × block interaction, $F_{(1,29)} = 0.56$, $P = 0.46$. Similarly, on the performance trials, there was no main effect of group, $F_{(1,29)} = 1.29$, $P = 0.27$ or block, $F_{(3,29)} = 0.47$, $P = 0.70$ and no group × block interaction, $F_{(3,29)} = 0.51$, $P = 0.68$. However, both groups performed better on the performance trials than the learning trials, $F_{(1,29)} = 22.50$, $P = 0.00005$, $\eta^2 = 0.44$. Despite no group differences, the PVL model indicated differences in underlying decision-making processes (Table 3). Strategic problem gamblers exhibited greater sensitivity to the magnitude of gains (higher utility shape), more sensitivity to losses (higher loss aversion), and more erratic or random choices (lower consistency) than controls. There was no difference on the recency/learning parameter.

Non-strategic problem gamblers performed similarly to controls on the learning trials, with no main effect of group, $F_{(1,42)} = 1.18$, $P = 0.28$ or block, $F_{(1,42)} = 0.68$, $P = 0.41$; however, there was a main effect of gender, $F_{(1,42)} = 4.62$, $P = 0.04$, $\eta^2 = 0.09$, indicating that men performed better than women (Fig. 2). We also found a group × block interaction, $F_{(1,42)} = 4.45$, $P = 0.04$, $\eta^2 = 0.09$, demonstrating that controls, but not problem gamblers, improved on the learning trials. No group × gender interaction was found, $F_{(1,42)} = 0.41$, $P = 0.53$. On the performance trials, we found a main effect of group, $F_{(1,45)} = 8.40$, $P = 0.006$, $\eta^2 = 0.17$ and gender, $F_{(1,42)} = 6.21$, $P = 0.02$, $\eta^2 = 0.13$, indicating that non-strategic problem gamblers performed worse than controls, and men performed better than women. However, there was no main effect of block, $F_{(3,42)} = 0.97$, $P = 0.41$ and no group × block, $F_{(3,42)} = 2.06$, $P = 0.11$ or group × gender interaction, $F_{(1,42)} = 3.08$, $P = 0.09$. In addition, controls, but not non-strategic problem gamblers, performed better on the performance trials than the learning trials, $F_{(1,42)} = 7.32$, $P = 0.01$, $\eta^2 = 0.15$, indi-

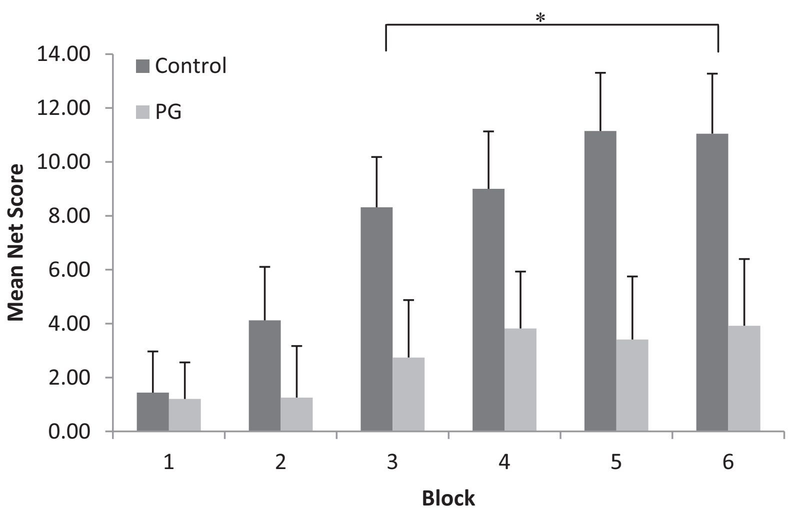

Figure 1 Overall group performances on the Iowa Gambling Task (IGT) represented as mean net score per block. Error bars represent standard error of the mean. Problem gamblers (PGs) performed more poorly than controls on the performance trials (blocks 3–6) with a significant group effect. *$P < 0.05$

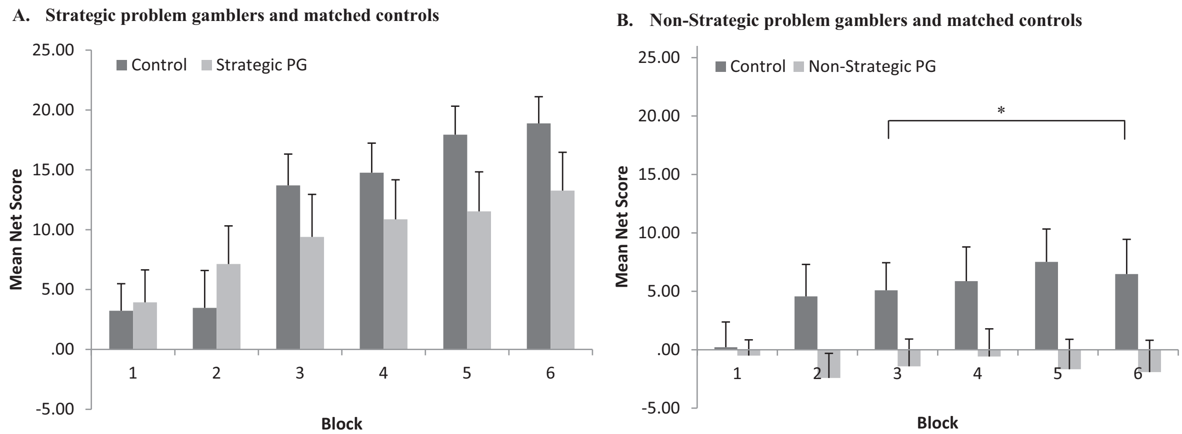

Figure 2 Strategic and non-strategic problem gamblers (PGs) and their respective matched control groups performance on the Iowa Gambling Task (IGT) represented as mean net score per block. Error bars represent standard error of the mean. (a) Strategic PGs did not differ from matched controls on the IGT. (b) Non-strategic PGs performed more poorly than their respective controls on the performance trials (blocks 3–6) with a significant group effect. **P* < 0.05

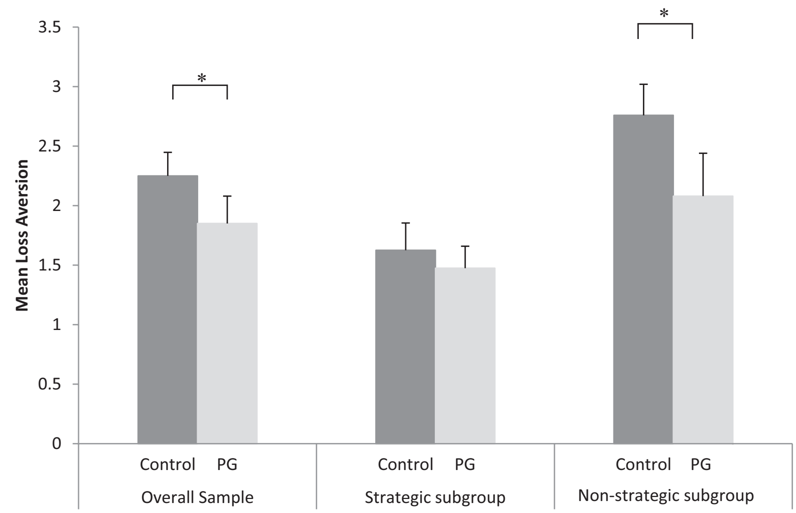

Figure 3 Mean loss aversion (λ) for problem gamblers (PGs) compared to representive matched control groups. Error bars represent standard error of the mean. **P* < 0.05

cating that unlike the strategic problem gamblers, non-strategic problem gamblers did not demonstrate learning on the IGT. The PVL model indicated that non-strategic problem gamblers demonstrated less sensitivity to losses than controls (lower loss aversion, Table 3). Groups did not differ on the recency/learning, consistency or utility shape parameters.

Performance on the Loss Aversion task

Overall, problem gamblers [mean = 1.85, standard deviation (SD) = 1.37] demonstrated less loss aversion than controls (mean = 2.25, SD = 1.22), $F_{(1,67)} = 56.53$, $P = 0.01$, $\eta^2 = 0.09$ (Fig. 3). We also found a main effect for gender, with women (mean = 2.52, SD = 1.49) displaying higher loss aversion than men (mean = 1.63, SD = 0.92), $F_{(1,67)} = 8.08$, $P = 0.01$, $\eta^2 = 0.10$, highlighting gender differences in decision-making, which are a key consideration for understanding the problem gamblers subtypes. With regard to gambler subgroups, strategic problem gamblers (mean = 1.47, SD = 0.66) did not differ from controls (mean = 1.63, SD = 0.94), $F_{(1,27)} = 0.19$, $P = 0.89$. In contrast, non-strategic problem gamblers (mean = 2.08, SD = 1.64) were less loss averse than controls (mean = 2.76, SD = 1.20), $F_{(1,39)} = 5.70$, $P = 0.02$, $\eta^2 = 0.13$.

DISCUSSION

Overall, problem gamblers made more disadvantageous choices on the IGT and displayed less sensitivity to losses during the loss aversion task. Using cognitive modelling for the first time with problem gamblers, we also showed that problem gamblers' IGT performance was underpinned by greater attention to the magnitude of gains and less choice consistency than controls. Our findings that problem gamblers performed poorly on both decision-making tasks is consistent with past research using the IGT [4,6,52] and other risky decision-making tasks [10–12], and highlights that particular decision-making styles may underlie problem gambling. Furthermore, substance abusers perform similarly [53,54], and display similar IGT cognitive modelling parameters [47,54,55] to problem gamblers, further supporting the concept of problem gambling as an addictive disorder.

A key feature of our study was the separate groups of strategic and non-strategic problem gamblers, which yielded novel insights into how problem gambling subgroups differ in decision processes. Strategic problem gamblers performed as well as their controls on the IGT but showed greater attention to gains, more sensitivity to losses and less choice consistency. In contrast, non-strategic problem gamblers performed worse than their controls and showed less sensitivity to losses. Although we did not directly compare the gambling subtypes, strategic problem gamblers appeared to perform better on the IGT than non-strategic problem gamblers, suggesting that strategic problem gamblers do indeed use strategies during ambiguous decision-making. Further differences were observed in the loss aversion task, with strategic problem gamblers performing similarly to their controls whereas, consistent with the IGT results, non-strategic problem gamblers were less loss averse than their controls. Interestingly, on the loss aversion task, strategic problem gamblers appear to be less loss averse than non-strategic problem gamblers; however their IGT choices were associated with more sensitivity to losses. These findings suggest that strategic problem gamblers' loss sensitivity may alter under conditions of risk and ambiguity. Collectively, our findings indicate differing underlying decision styles in strategic and non-strategic problem gamblers. Heterogeneity among problem gamblers' decision-making has also been shown in EGM and casino problem gamblers [4]. Strategic gambling activities may include more analytical decision-making processes [29], which may enable strategic problem gamblers to learn the IGT better than non-strategic problem gamblers.

As the strategic problem gamblers were all men and the non-strategic problem gamblers were mainly women, we took gender into account by using gender-matched controls, thus making it possible highlight differences in the gambling subtypes. However, considering our data from the gender viewpoint, we found that men performed better on the IGT and women demonstrated higher loss aversion. These findings are consistent with research showing that women require longer to learn the IGT [33,34] and are more loss averse during risky gambles than men [35], highlighting the importance of considering gender in decision-making research.

Our cognitive modelling results showed that problem gamblers demonstrated altered reward processing during decision-making. Similarly, neuroimaging findings suggest that problem gamblers have reduced activation in reward regions (ventral striatum and ventromedial prefrontal cortex) during monetary gains [56] and while processing rewards and losses [23]. Our results provide further evidence that aberrant reward processing may be a key factor involved in problem gamblers' decision-making, and further add that reward processing appears to be altered differentially for gambling subgroups. That is, strategic problem gamblers showed altered gain and loss processing, while non-strategic problem gamblers demonstrated less sensitivity only to losses. However, our results cannot determine whether altered reward processing is present prior to the development of problem gambling or occurs as a consequence of excessive gambling. Furthermore, we do not yet know whether neuroimaging studies would confirm these cognitive findings, in the form of differential brain activation patterns.

Our findings that problem gamblers (regardless of subtype) and controls demonstrated similar recency/learning parameters indicates that IGT performance may not be due to poor learning or memory. This is consistent with findings that problem gamblers do not demonstrate memory impairments [57] and working memory is unrelated to their IGT performance [11]. We also found that the overall problem gambling sample, and strategic but not non-strategic problem gamblers, demonstrated lower choice consistency on the IGT. This parameter may relate to impulsivity [47] and high self-reported impulsivity is common in problem gamblers [58,59], which may be a greater issue for strategic problem gamblers.

We note that our sample was treatment-seeking, which limits generalization to problem gamblers who do not seek treatment, many of whom recover naturally [60]. Moreover, to enhance generalizability, we retained comorbidities in our problem gambling sample and controlled for depressive and anxiety symptoms in the analysis. However, we note that common problem gambling comorbidities (e.g. depression, anxiety, alcohol and substance use disorders) can be associated with poor decision-making [54,61–63] and may have influenced our results. Furthermore, as our controls were, in essence, non-gamblers, our study did not compare non-problem gamblers to problem gamblers to isolate specific decision-making styles associated with problem gambling in comparison to non-problem gambling. Future research should include regular non-problem gamblers as a comparison group.

In summary, our study is the first to use cognitive modelling to understand problem gamblers' decision-making, and our findings provide a novel insight into differences between problem gambling subtypes. Strategic problem gamblers decisions are influenced by both gains and losses, and they tend to have an inconsistent, possibly impulsive, choice style. In contrast, non-strategic problem gamblers are less sensitive to losses and show poor learning during decision-making. Our findings highlight the presence of important cognitive differences between problem gambling subtypes which require further investigation.

Declaration of interests

None.

Acknowledgements

This project was funded in part by the National Association for Gambling Studies Annual Research Grant. The authors also wish to acknowledge partial support for this project from the Australian Research Council, ARC Discovery Project 110100696 (Stout CIA). P.G.E. is supported by a National Health and Medical Research Council Clinical Research Fellowship.

References

1. American Psychiatric Association (APA). *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*. Arlington, VA: American Psychiatric Publishing; 2013.
2. Bechara A. Decision making, impulse control and loss of willpower to resist drugs: a neurocognitive perspective. *Nat Neurosci* 2005; **8**: 1458–63.
3. Coventry K. R. Gambling and decision-making: a dual process perspective. *Behav Brain Sci* 2008; **31**: 444–5.
4. Goudriaan A. E., Oosterlaan J., de Beurs E., van den Brink W. Decision making in pathological gambling: a comparison between pathological gamblers, alcohol dependents, persons with Tourette syndrome, and normal controls. *Brain Res Cogn Brain Res* 2005; **23**: 137–51.
5. Cavedini P., Riboldi G., Keller R., D'Annucci A., Bellodi L. Frontal lobe dysfunction in pathological gambling patients. *Biol Psychiatry* 2002; **51**: 334–41.
6. Ledgerwood D., Orr E., Kaploun K., Milosevic A., Frisch G., Rupcich N. *et al*. Executive function in pathological gamblers and healthy controls. *J Gambl Stud* 2012; **28**: 89–103.
7. Petry N. M. Pathological gamblers, with and without substance use disorders, discount delayed rewards at high rates. *J Abnorm Psychol* 2001; **110**: 482–7.
8. Dixon M. R., Marley J., Jacobs E. A. Delay discounting by pathological gamblers. *J Appl Behav Anal* 2003; **36**: 449–58.
9. Lakey C. E., Goodie A. S., Campbell W. Frequent card playing and pathological gambling: the utility of the Georgia Gambling Task and Iowa Gambling Task for predicting pathology. *J Gambl Stud* 2007; **23**: 285–97.
10. Labudda K., Wolf O. T., Markowitsch H. J., Brand M. Decision-making and neuroendocrine responses in pathological gamblers. *Psychiatry Res* 2007; **153**: 233–43.
11. Brevers D., Cleeremans A., Goudriaan A. E., Bechara A., Kornreich C., Verbanck P. *et al*. Decision making under ambiguity but not under risk is related to problem gambling severity. *Psychiatry Res* 2012; **200**: 568–74.
12. Brand M., Kalbe E., Labudda K., Fujiwara E., Kessler J., Markowitsch H. J. Decision-making impairments in patients with pathological gambling. *Psychiatry Res* 2005; **133**: 91–9.
13. Toplak M. E., Liu E., Macpherson R., Toneatto T., Stanovich K. E. The reasoning skills and thinking dispositions of problem gamblers: a dual-process taxonomy. *J Behav Decis Making* 2007; **20**: 103–24.
14. Busemeyer J. R., Stout J. C. A contribution of cognitive decision models to clinical assessment: decomposing performance on the Bechara gambling task. *Psychol Assess* 2002; **14**: 253–62.
15. Ahn W.-Y., Busemeyer J. R., Wagenmakers E.-J., Stout J. C. Comparison of decision learning models uing the generalization criterion method. *Cogn Sci* 2008; **32**: 1376–402.
16. Yechiam E., Busemeyer J. R., Stout J. C., Bechara A. Using cognitive models to map relations between neuropsychological disorders and human decision-making deficits. *Psychol Sci* 2005; **16**: 973–8.
17. Tversky A., Kahneman D. Advances in prospect theory: cumulative representation of uncertainty. *J Risk Uncertain* 1992; **5**: 297–323.
18. Tversky A., Kahneman D. Loss aversion in riskless choice: a reference-dependent model. *Q J Econ* 1991; **106**: 1039–61.
19. Bibby P. A., Ferguson E. The ability to process emotional information predicts loss aversion. *Pers Individ Dif* 2011; **51**: 263–6.
20. Sokol-Hessner P., Camerer C. F., Phelps E. A. Emotion regulation reduces loss aversion and decreases amygdala responses to losses. *Soc Cogn Affect Neurosci* 2013; **8**: 341–50.
21. Tremeau F., Brady M., Saccente E., Moreno A., Epstein H., Citrome L. *et al*. Loss aversion in schizophrenia. *Schizophr Res* 2008; **103**: 121–8.
22. de Ruiter M. B., Veltman D. J., Goudriaan A. E., Oosterlaan J., Sjoerds Z., Van Den Brink W. Response perseveration and ventral prefrontal sensitivity to reward and punishment in male problem gamblers and smokers. *Neuropsychopharmacology* 2009; **34**: 1027–38.
23. Balodis I. M., Kober H., Worhunsky P. D., Stevens M. C., Pearlson G. D., Potenza M. N. Diminished frontostriatal activity during processing of monetary rewards and losses in pathological gambling. *Biol Psychiatry* 2012; **71**: 749–57.
24. Goudriaan A. E., Oosterlaan J., de Beurs E., van den Brink W. Psychophysiological determinants and concomitants of deficient decision making in pathological gamblers. *Drug Alcohol Depend* 2006; **84**: 231–9.
25. Milosevic A., Ledgerwood D. M. The subtyping of pathological gambling: a comprehensive review. *Clin Psychol Rev* 2010; **30**: 988–98.
26. Nower L., Martins S. S., Lin K.-H., Blanco C. Subtypes of disordered gamblers: results from the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC). *Addiction* 2013; **108**: 789–98.
27. Blaszczynski A., Nower L. A pathways model of problem and pathological gambling. *Addiction* 2002; **97**: 487–99.
28. Petry N. M. A comparison of treatment-seeking pathological gamblers based on preferred gambling activity. *Addiction* 2003; **98**: 645–55.
29. Odlaug B., Marsh P., Kim S., Grant J. Strategic vs non-strategic gambling: characteristics of pathological gamblers based on gambling preference. *Ann Clin Psychiatry* 2011; **23**: 105–12.

30. Grant J. E., Odlaug B. L., Chamberlain S. R., Schreiber L. R. N. Neurocognitive dysfunction in strategic and non-strategic gamblers. *Prog Neuropsychopharmacol Biol Psychiatry* 2012; **38**: 336–40.
31. Breen R., Zimmerman M. Rapid onset of pathological gambling in machine gamblers. *J Gambl Stud* 2002; **18**: 31–43.
32. Potenza M. N., Steinberg M. A., McLaughlin S. D., Wu R. M. S., Rounsaville B. J., O'Malley S. S. Gender-related differences in the characteristics of problem gamblers using a gambling helpline. *Am J Psychiatry* 2001; **158**: 1500–5.
33. van den Bos R., Homberg J., de Visser L. A critical review of sex differences in decision-making tasks: focus on the Iowa Gambling Task. *Behav Brain Res* 2013; **238**: 95–108.
34. van den Bos R., Jolles J., van der Knaap L., Baars A., de Visser L. Male and female Wistar rats differ in decision-making performance in a rodent version of the Iowa Gambling Task. *Behav Brain Res* 2012; **234**: 375–9.
35. Brooks P., Zank H. Loss averse behavior. *J Risk Uncertain* 2005; **31**: 301–25.
36. Ferris J., Wynne H. The Canadian Problem Gambling Index: final report. Ottawa, Canada: Canadian Centre on Substance Abuse (CCSA), 2001.
37. Nelson H. E., Willison J. *National Adult Reading Test (NART): Test Manual*, 2nd edn. Windsor, UK: NFER Nelson; 1991.
38. Crawford J. R., Deary I. J., Starr J., Whalley L. J. The NART as an index of prior intellectual functioning: a retrospective validity study covering a 66-year interval. *Psychol Med* 2001; **31**: 451–8.
39. Wiens A. N., Bryan J. E., Crossen J. R. Estimating WAIS-R FSIQ from the national adult reading test-revised in normal subjects. *Clin Neuropsychol* 1993; **7**: 70–84.
40. Blair J. R., Spreen O. Predicting premorbid IQ: a revision of the national adult reading test. *Clin Neuropsychol* 1989; **3**: 129–36.
41. Sheehan D. V., Lecrubier Y. MINI International Neuropsychiatric Interview. 2006.
42. Lovibond S. H., Lovibond P. E. *Manual for the Depression Anxiety Stress Scales*. Sydney, Australia: Psychology Foundation of Australia; 1995.
43. World Health Organization. The Alcohol Use Disorders Identification Test (AUDIT). Geneva: World Health Organization, 2001.
44. Lorains F. K., Cowlishaw S., Thomas S. A. Prevalence of comorbid disorders in problem and pathological gambling: systematic review and meta-analysis of population surveys. *Addiction* 2011; **106**: 490–8.
45. Bechara A., Damasio A. R., Damasio H., Anderson S. W. Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition* 1994; **50**: 7–15.
46. Bechara A., Damasio H., Damasio A. R., Lee G. P. Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *J Neurosci* 1999; **19**: 5473–81.
47. Fridberg D. J., Queller S., Ahn W.-Y., Kim W., Bishara A. J., Busemeyer J. R. *et al*. Cognitive mechanisms underlying risky decision-making in chronic cannabis users. *J Math Psychol* 2010; **54**: 28–38.
48. De Martino B., Camerer C. F., Adolphs R. Amygdala damage eliminates monetary loss aversion. *Proc Natl Acad Sci USA* 2010; **107**: 3788–92.
49. Tom S. M., Fox C. R., Trepel C., Poldrack R. A. The neural basis of loss aversion in decision-making under risk. *Science* 2007; **315**: 515–8.
50. Brand M., Recknor E. C., Grabenhorst F., Bechara A. Decisions under ambiguity and decisions under risk: correlations with executive functions and comparisons of two different gambling tasks with implicit and explicit rules. *J Clin Exp Neuropsychol* 2007; **29**: 86–99.
51. Preston S. D., Buchanan T. W., Stansfield R. B., Bechara A. Effects of anticipatory stress on decision making in a gambling task. *Behav Neurosci* 2007; **121**: 257–63.
52. Kertzman S., Lidogoster H., Aizer A., Kotler M., Dannon P. N. Risk-taking decisions in pathological gamblers is not a result of their impaired inhibition ability. *Psychiatry Res* 2011; **188**: 71–7.
53. Verdejo-García A. J., Perales J. C., Pérez-García M. Cognitive impulsivity in cocaine and heroin polysubstance abusers. *Addict Behav* 2007; **32**: 950–66.
54. Stout J. C., Rock S. L., Campbell M. C., Busemeyer J. R., Finn P. R. Psychological processes underlying risky decisions in drug abusers. *Psychol Addict Behav* 2005; **19**: 148–57.
55. Stout J. C., Busemeyer J. R., Lin A., Grant S. J., Bonson K. R. Cognitive modeling analysis of decision-making processes in cocaine abusers. *Psychon Bull Rev* 2004; **11**: 742–7.
56. Reuter J., Raedler T., Rose M., Hand I., Glascher J., Buchel C. Pathological gambling is linked to reduced activation of the mesolimbic reward system. *Nat Neurosci* 2005; **8**: 147–8.
57. Goudriaan A. E., Oosterlaan J., de Beurs E., van den Brink W. Neurocognitive functions in pathological gambling: a comparison with alcohol dependence, Tourette syndrome and normal controls. *Addiction* 2006; **101**: 534–47.
58. Ledgerwood D. M., Alessi S. M., Phoenix N., Petry N. M. Behavioral assessment of impulsivity in pathological gamblers with and without substance use disorder histories versus healthy controls. *Drug Alcohol Depend* 2009; **105**: 89–96.
59. Maccallum F., Blaszczynski A., Ladouceur R., Nower L. Functional and dysfunctional impulsivity in pathological gambling. *Pers Individ Dif* 2007; **43**: 1829–38.
60. Slutske W. S. Natural recovery and treatment-seeking in pathological gambling: results of two U.S. national surveys. *Am J Psychiatry* 2006; **163**: 297–302.
61. Blanco N. J., Otto A. R., Maddox W. T., Beevers C. G., Love B. C. The influence of depression symptoms on exploratory decision-making. *Cognition* 2013; **129**: 563–8.
62. Cella M., Dymond S., Cooper A. Impaired flexible decision-making in major depressive disorder. *J Affect Disord* 2010; **124**: 207–10.
63. Bechara A., Damasio H. Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia* 2002; **40**: 1675–89.

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1 Supplementary methods.

