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Decision making under ambiguity but not under risk is related to problem gambling severity

Damien Brevers [a,*], Axel Cleeremans [a], Anna E. Goudriaan [b], Antoine Bechara [c,d,e], Charles Kornreich [a], Paul Verbanck [a], Xavier Noël [a]

[a] Psychological Medicine Laboratory, Université Libre de Bruxelles, Belgium
[b] Academic Medical Center, Department of Psychiatry, University of Amsterdam, Netherlands
[c] Brain and Creativity Institute and Department of Psychology, University of Southern California, CA, USA
[d] Clinical Research Division, Douglas Mental Health University Institute, Montreal, QC, Canada
[e] Department of Neurology, University of Iowa, IA, USA

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ABSTRACT

The aim of the present study was to examine the relationship between problem gambling severity and decision-making situations that vary in two degrees of uncertainty (probability of outcome is known: decision-making under risk; probability of outcome is unknown: decision-making under ambiguity). For this purpose, we recruited 65 gamblers differing in problem gambling severity and 35 normal controls. Decision-making under ambiguity was assessed with the Iowa Gambling Task (IGT) and the Card Playing Task (CPT). Decision-making under risk was assessed with the Coin Flipping Task (CFT) and the Cups Task. In addition, we included an examination of two working memory components (verbal storage and dual tasking). Results show that problem gamblers performed worse than normal controls on both ambiguous and risky decision-making. Higher problem gambling severity scores were associated with poorer performance on ambiguous decision-making tasks (IGT and CPT) but not decision-making under risk. Additionally, we found that dual task performance correlated positively with decision-making under risk (CFT and Cups tasks) but not with decision-making under ambiguity (IGT and CPT). These results suggest that impairments in decision-making under uncertain conditions of problem gamblers may represent an important neurocognitive mechanism in the maintenance of their problem gambling.

1. Introduction

For many people, gambling represents a recreational activity (e.g., occasional lottery players). However, for some of them (e.g., 1.6% in France; Inserm, 2008) their gambling habits continue despite a rise in negative consequences. Addicted gamblers persist in playing and often explain their gambling behavior with many reasons, but the fact is that negative consequences directly associated to gambling do not result in diminished gambling in these players, and that these negative consequences are thus weak regulators of their gambling (DSM-IV-TR). One explanation of problem gambling views addiction to gambling as the result of impaired decision made under uncertainty (Bechara, 2003).

Abnormal patterns of decision-making in pathological gamblers can be described by their decision-making preferences for alternatives featuring high-risk, high-reward, short-term gains with a long-term lower overall expected value—and thus a less adaptive strategy (e.g., Bechara, 2003, 2005). Poor decision may reflect a number of underlying deficits, including impaired pre-choice emotional activation and feedback processing (gains or losses; e.g., Goudriaan et al., 2006, 2008), and also impairments in executive supervision (for a review see Goudriaan et al. (2004) and van Holst et al. (2010)). In addition, underlying processes may depend upon the degree of uncertainty and the amount of information offered to the decision maker (e.g., Brand et al., 2006). Indeed, for behavioral economists, decisions made under uncertain situations can be divided into two types: decisions made under risk, that is, where probabilities are known; and decision made under ambiguity, that is, where outcome probabilities are not completely known (e.g., Kahneman and Tversky, 1979). Therefore, one goal of this study was to further specify whether the decision-making impairment in problem gamblers is more related to decisions under risk or under ambiguity.

Whereas it is possible that risky and ambiguous decisions may rely on the same underlying processes, as both require a choice without certain knowledge of the outcome, it is also possible that different processes may support these two forms

* Correspondence to: Psychological Medicine Laboratory, CHU-Brugmann University Libre de Bruxelles, Place Van Gehuchten, 4, 1020 Brussels, Belgium. Tel.: +322473130.
E-mail address: dbrevers@ulb.ac.be (D. Brevers).

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of decision-making (e.g., Brand et al., 2006). Two possible underlying mechanisms may influence impaired decision made under these two types of uncertain situations: (1) a disturbance of pre-choice emotional activation and feedback processing, which might result in both impairments in decision-making under ambiguity (e.g., Bechara et al., 1997) and in decision-making under risk (e.g., Weller et al., 2007); (2) less supervision by the executive system which would result in disadvantageous risky decisions (Brand et al., 2005a,b). Moreover, neuroimaging data support this distinction. On the one hand, decision-making under ambiguity and under risk may be associated with activity in the orbito-frontal and the ventromedial prefrontal cortex with regard to the use of feedback to improve decision-making (e.g., Paulus et al., 2001). On the other hand, decision-making under risk, but not under ambiguity, depends on the integrity of the dorsolateral prefrontal loop (e.g., Brand et al., 2006). These regions are critical for overseeing subordinate processes through the exercise of executive control (e.g., Starcke et al., 2011).

Problem gamblers exhibit a variety of decision-making impairments. First, addiction to gambling was associated with both impaired decision-making under risk (e.g., Brand et al., 2005a,b) and under ambiguity (e.g., Roca et al., 2008). Second, problem gamblers' impairment on decision-making under risk was associated with both executive (Brand et al., 2005a,b) and feedback (Labudda et al., 2007) processes. Furthermore, problem gamblers' impairment on decisions making under ambiguity was associated with disturbance of pre- and post-choice emotional activation (Goudriaan et al., 2006). Nevertheless, a direct comparison of decision-making performance under ambiguity and under risk has not yet been made in problem gambling. Thus, it is unclear whether impairment in one type of decision-making may be more pronounced in problem gambling than the other, and to what extent these two kinds of abnormalities in decision-making are related to the severity of their problem gambling. For instance, in other mental disorders such as obsessive-compulsive disorders, Starcke et al. (2010) found higher disturbance in decision-making under ambiguity compared to decision-making under risk.

The relation between decision-making impairments and the magnitude of problem gambling severity appears to be crucial. In college students, the severity of gambling problems was higher in those students with an impaired capacity to decide advantageously under uncertainty (Lakey et al., 2007). This study aimed to investigate the relationship between problem gambling severity and both decision-making under risk and decision-making under ambiguity in a sample of problem gamblers ranging from low problem gambling to more severe pathological gambling. A normal control group (matched on age, sex and intelligence) was also included in the present research in order to make comparison in their scores. Firstly, we aimed to investigate the effect of problem gambling on decision-making. We hypothesize that problem gamblers, compared to normal controls, have a more impaired performance on decision-making tasks under ambiguity, as measured by the Iowa Gambling Task (Bechara et al., 1994) and the Card Playing Task (Newman et al., 1987), and on decision-making tasks under risk, as measured by the Coin Flipping Task (Tom et al., 2007) and the Cups Task (Levin et al., 2007). Secondly, we aimed to investigate the relation between problem gambling severity and decision-making. We hypothesize that disadvantageous decision-making (under ambiguity and under risk) is positively correlated with problem gambling severity. Additionally, we hypothesize that performance on working memory related components will only be correlated with decision-making under risk. We also assume that diminished performance in problem gamblers remains after controlling for the effect of potential confounders such as anxiety, depression and ADHD.

2. Methods

2.1. Participants and recruitment

Sixty-five problem gamblers and 35 normal controls participated in the study. Gamblers were recruited through advertisements in the casino complex *VIAGE*, Brussels, Belgium. The ads asked for participants who "gambled frequently" to participate in a one-day study to explore factors associated with gambling. In order to exclude occasional or non-frequent gamblers, a screening interview was conducted by means of a locally developed screening tool which included an examination of frequency of gambling behavior and comorbid psychiatric disorders. We excluded any subject who was (a) over 65 years, or (b) experienced either a substance use disorder during the year before enrollment into the study. Participants were judged to be medically healthy on the basis of their medical history. The severity of problems related to substance use and medical history were examined with items taken from the Addiction Severity Index Short Form (McLellan et al., 1992; the selection of items was undertaken by S.M. and P.V.; CHU-Brugmann board-certified psychotherapists).

All gamblers had a minimal score of 3 on the South Oaks Gambling Screen (SOGS, Lesieur and Blume, 1987), 33 respondents (51%) met the criteria for probable pathological gambling (SOGS $\geq$ 5). In addition, pathological gambling was assessed by using the DSM-IV-TR. We observed that none of the participants who scored between 3 and 4 on the SOGS met the DSM-IV criteria for pathological gambling; 14 (70%) of the 20 respondents who scored between 5 and 7 on the SOGS met the DSM-IV criteria for pathological gambling; all of the 13 respondents who scored between 8 or higher on the SOGS met the DSM-IV criteria for pathological gambling. Thus, a total of 27 pathological gamblers was included in the study. On the basis of Lawrence et al. (2009), we will refer to this combined group henceforth as problem gamblers.

Normal control participants were recruited by word of mouth from the community. To avoid biases, resulting from inside knowledge of how these tasks operate, psychiatrists, psychologists and other personnel with previous psychological training were excluded from participation. On the SOGS, only 7 controls (20%) reported playing the numbers or betting on lotteries occasionally (i.e., less than once a week) over the past 12 months preceding testing. None of the other controls gambled.

2.2. Current clinical status

Current clinical status of depression and anxiety levels were rated with the Beck Depression Inventory (BDI; Beck et al., 1961), the Spielberger State–Trait Anxiety Inventory (STAI; Spielberger, 1983), and the Adult ADHD Self-Report Scale (ASRS-v1.1; Kessler et al., 2005), respectively.

We assessed intelligence with two subtests of the WAIS: block design and vocabulary (Wechsler, 2000). This short form of the WAIS correlates with the full scale WAIS IQ in the 0.90 range (Groth-Marnat, 1997).

2.3. Decision-making task

2.3.1. Decision-making under ambiguity

2.3.1.1. The Iowa gambling task (IGT; Bechara et al., 1994). This task investigates decision-making under ambiguity with both uncertain probability and uncertain value of reward and loss. In this task, participants sat in front of four decks of cards that were identical in appearance, except for their labels A, B, C and D. They were told that the goal of the task was to earn as much money as possible. Participants were informed that each trial would consist of a deck selection and the turning over of one card from the selected deck to reveal the yield. Participants were informed that they were free to switch between decks at any time, and as often as desired. The net outcome of choosing from either deck A or deck B was a loss of five times the average per ten cards (referred to as disadvantageous decks), and the net outcome of choosing from either decks C or D was a gain of five times the average per ten cards (advantageous decks). The total number of trials was set at 100 card selections. The dependent measure was the number of cards picked from the advantageous decks in each stage of 20 cards.

2.3.1.2. The card playing task (CPT; adapted from Newman et al. (1987) by Goudriaan et al. (2005)). This task investigates decision-making under ambiguity with uncertain probability of reward and loss but fixed value of reward and loss. On the computer screen, the backside of a card appeared. Number cards resulted in a loss of 50 eurocents. Face cards resulted in winning 50 eurocents. Participants could choose to play a card or choose to quit the task. The task consisted of 10 blocks of 10 cards. In each block of cards, the ratio of wins to losses changed; the number of cards increased with one loss card in each block and decreased with one win card; in the first block, the ratio of wins to losses was 9 to 1, in the second block 8 to 2, and so on. Participants were not notified of changes in ratios of wins to losses. In order to prevent differential effects of early or late losses on quitting the task, the cards were presented in a semi-random order, which was equivalent for all participants. The dependent measure was the number of cards played, divided into four categories: (1) selection of 33–52 cards resulted in an optimal strategy, with a maximum amount of money earned (9.50–11 euros); (2) a total of 1–32 cards played resulted in a suboptimal amount of money earned (up to 9 euros), due to a conservative selection approach; (3) selection of 53–100 cards resulted in a suboptimal amount of money earned (9–0.50 euros), due to a perseverative card selection strategy; (4) the fourth category corresponded to a performance in which the participant wanted to play more than 100 times and was stopped by the computer which resulted in a suboptimal amount of money earned (zero euro), due to an extremely perseverative card selection strategy.

2.3.2. Decision-making under risk

2.3.2.1. The coin flipping task (CFT, adapted from Tom et al. (2007)). This task investigates decision-making under risk with fixed probability. Participants decided whether to accept or reject mixed gambles that offered a 50/50 chance of either gaining one amount of money or losing another amount. We asked participants to indicate one of four responses to each gamble (strongly accept, weakly accept, weakly reject, and strongly reject). The sizes of the potential gain and loss were manipulated independently, with gains ranging from 10 to 40 euro (in increments of 2 euro) and losses ranging from 5 to 20 euro (in increments of 1 euro), resulting in 256 random trials. The dependent measure was the participant's gamble acceptance for six computed win/loss ratio that include trials in which (1) the potential gain equaled the potential loss, trials where potential gain was maximum (2) twice, (3) twice point five, (4) thrice, (5) four times or (6) eight times the amount of the potential loss.

2.3.2.2. The Cups task (Levin et al., 2007). This task investigates decision-making under risk with both known probability and known value of reward and loss. This task includes a Gain domain, which consists of gain trials, with a choice between a sure gain and a gamble with a possible larger gain or no gain, and a Loss domain, which consists of loss trials with a choice between a sure loss and a gamble with a possible larger loss or no loss.

For both Gain and Loss domains trials, subjects were required to choose between the risky and the safe option. The safe option is to win or lose €1 for sure, whereas the risky option in the Gain domain could lead to a probability (0.20, 0.33, or 0.50) of a larger win (€2, €3, or €5) or could lead to no win. In the Loss domain, a risky choice could lead to a probability (0.20, 0.33, or 0.50) of losing more (€2, €3, or €5) or could lead to losing nothing. Probability levels and amounts of possible win or loss vary between trials. Hence, the expected value (EV) for the risky option shifts from more favorable to less favorable (see Table 1).

On each trial, an array of 2, 3, or 5 cups is shown on one side of the screen, with the possible gain or loss shown on top. This array is identified as the risky side where selection of one cup out of the total number of cups will lead to a designated number of euros gained (or lost) whereas a selection of the other cups will lead to no gain (or no loss). After participants made the choice, the gamble was resolved immediately, allowing them to experience the consequence of the risky or safe choice.

Gain and loss domains were presented as two separate blocks of 27 random trials, counterbalanced in order across participants in each group. There were 3 trials for each combination of domain, probability, and outcome magnitude. When the participant completed all 54 trials, their total amount won appeared on the screen. The dependent measure was the number of risky choices at each of three EV level (risk advantageous, risk equal, risk disadvantageous; see Table 1) for both the Gain and the Loss domains.

2.4. Working memory task

Working memory was assessed by two tasks: (1) as a measure of verbal storage, the Digit span task (forward) assessing capacity by determining the maximum length of numbers that participants can serially recall and (2) as a measure of central executive (processing of various types of information), the Operation-span Task (Ospan; Turner and Engle, 1989) in which subjects are requested to solve mathematical operations while simultaneously remembering a set of unrelated words. The Ospan score was calculated according to the partial credit unit scoring procedure (PCU; Conway et al., 2005).

Table 1
Expected value (EV) for the risky option on Gain and Loss domain of the Cups task according to probability level (P) and amount (in euro).

	Gain domain		Loss domain	
	P	€	P	€
Risk advantageous EV	0.33	5	0.20	3
	0.50	3	0.33	2
Risk equal EV	0.20	5	0.20	5
	0.33	3	0.33	3
	0.50	2	0.50	2
Risk disadvantageous EV	0.20	3	0.33	5
	0.33	2	0.50	3

2.5. Procedure

Participants were tested individually in a quiet room, located at the Medical Psychology Laboratory of the Brugmann Hospital. The order of test presentation was counterbalanced. No significant correlation between administration order and any of the performance measures was present. Participants received €40 for their participation.

2.6. Data analysis

First, we compared the performance of the problem gambler and control groups on all decision-making tasks separately. Analyses of variance (ANOVAs) with repeated measurements were performed to detect overall group differences or group by factor interactions in the profile of the IGT, the CFT and the Cups task performance. A chi square analysis was performed to examine performance on the CPT. One-way ANOVAs were performed for demographical data, current clinical status measures and working memory performance.

Second, in order to investigate the relationship between gambling dependence severity and decision-making performance, correlation analyses were conducted between scores on the SOGS and scores on IGT, CFT and Cups task (n=65). A univariate ANOVA was conducted to examine differences of problem gambling severity in function of number of cards played during the CPT (i.e., optimal, conservative, perseverative or extremely perseverative).

3. Results

3.1. Demographics and current clinical status

A description of demographic variables, working memory (Ospan), estimated IQ, ADHD (ASRS), depression (BDI) and anxiety (STAI-S; STAI-T), is presented in Table 2. ANOVA revealed that problem gamblers and normal controls were similar in terms of age and estimated IQ, as measured by the Block Design and Vocabulary subtests of the WAIS. Chi square analyses revealed no differences in the distribution of male and female participants. The problem gamblers had a higher ADHD score compared to controls, $F(1, 99)=31.21$, $p<0.001$. Depression was higher, $F(1, 99)=27.41$, $p<0.001$, in problem gamblers than in normal controls. State and Trait Anxiety was higher in problem gamblers compared to normal controls, $F(1, 99)=12.49$, $p<0.001$; $F(1, 99)=29.22$, $p<0.001$, respectively. No other group differences were present. When we carried out ANCOVAS using ADHD, depression, trait and state anxiety as covariates, we found no effect for any of these variables on comparisons between problem gamblers and controls; we therefore carried out ANOVAS.

3.1.1. Performance on decision-making under ambiguity

3.1.1.1. Iowa gambling task. A repeated measures ANOVA was performed, with group (normal controls versus problem gamblers) as a between-subjects factor; stage (5 stages of 20 trials) as a within subjects factor; and the net score of advantageous choice (C+D), as the dependent measure. This analysis revealed an effect of stage, $F(4, 96)=11.83$, $p<0.001$, $\eta^2=0.11$, indicating that task performance increased during the consecutive stages of the task; a group effect, $F(1, 99)=9.23$, $p<0.01$, $\eta^2=0.09$, indicating that normal controls performed better than problem gamblers; and a Group × Stage interaction, $F(4, 96)=6.65$, $p<0.05$, $\eta^2=0.09$, indicating that normal controls performed better than problem gamblers on stage three, four and five of the IGT (see Fig. 1).

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Table 2
Demographical data and standard deviations for normal controls and problem gamblers.

	Normal control	*Problem gamblers*	*Test statistics*	
n	35	65		
Age (SD)	43.24(10.69)	38.93(11.35)	$F(1, 98)=2.09$, *NS*	Control = gambler
Male/Female	29/6	50/15	$X^2(1, 99)=0.48$, *NS*	Control = gambler
WAIS VOC	44.61(6.30)	42.87(7.52)	$F(1, 99)=0.13$, *NS*	Control = gambler
WAIS BD REP	15.51(1.89)	14.62(2.51)	$F(1, 99)=2.81$, *NS*	Control = gambler
WAIS BD RT	19.30(5.59)	22.79(6.12)	$F(1, 99)=2.27$, *NS*	Control = gambler
ASRS	7.63(3.31)	13.35(5.32)	$F(1, 99)=31.21$, $p<0.001$	Control < gamblers
BDI	2.29(2.47)	8.90(5.96)	$F(1, 99)=27.41$, $p<0.001$	Control < gamblers
STAI-E	31.29(9.96)	40.12(11.67)	$F(1, 99)=12.49$, $p<0.001$	Control < gamblers
STAI-T	36.64(7.31)	48.12(11.44)	$F(1, 99)=29.22$, $p<0.001$	Control < gamblers
SOGS	0.00(0.00)	7.07(3.74)		

Note. Values shown are the mean and standard deviations on each measure. The South Oaks Gambling Screen was administered only in the gamblers groups. Degrees of freedom differ due to missing data. Ospan = Operation span task, WAIS VOC = WAIS vocabulary, WAIS BD REP = WAIS block design correct responses, WAIS BD RT = WAIS bloc design reaction time, ASRS = Adult ADHD self-report, BDI = Beck Depression Inventory, STAI-E = State version of the State-Trait Anxiety Inventory, STAI-T = Trait version of the State-Trait Anxiety Inventory, SOGS = South Oaks Gambling Screen.

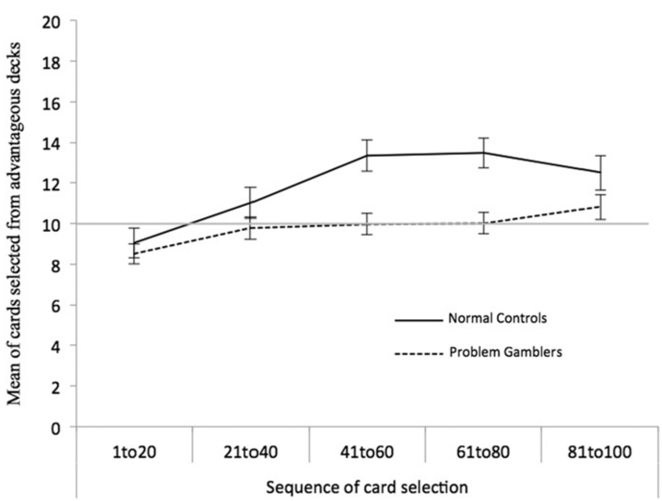

Fig. 1. Means of the total number of cards selected from the advantageous decks for each stage of 20 card choices on the Iowa Gambling Task by normal controls and problem gamblers, with 10 indicating no preference for advantageous or disadvantageous decks. Error bars are the standard errors of the mean.

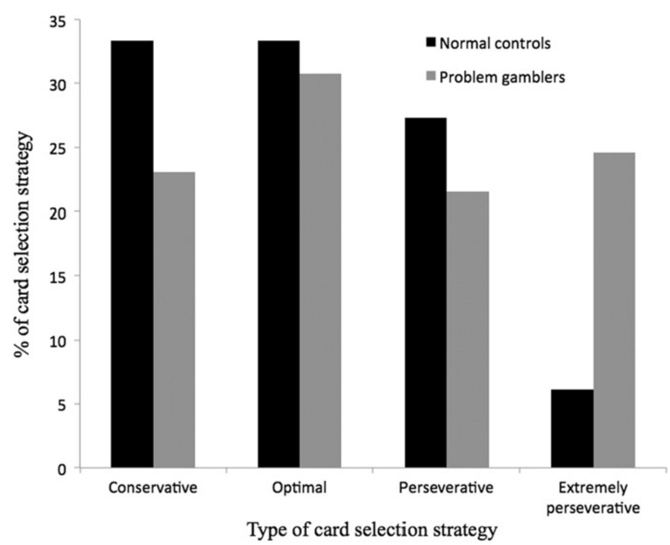

Fig. 2. Percentage of conservative (0–31 played trials), optimal (32–52), perseverative (53–99) or extremely perseverative (100+) card selection on the Card Playing Task by normal controls and problem gamblers.

3.1.1.2. Card playing task. The proportion of participants in each group that picked cards in a conservative, optimal, perseverative, or an extremely perseverative way is displayed in Fig. 2. A chi square analysis was performed with group as the independent variable and card selection strategy as the dependent variable. The groups tended to differ with regard to the selection of cards across all categories but the effect did not reach significance, $X^2(3, N=100)=6.89$, $p=0.075$. Follow up analyses, comparing either the conservative (0–32 played trials), perseverative (53–99) or extremely perseverative (100+) with the optimal card selection strategy (33–52), indicated that problem gamblers performed worse than normal controls due to more subjects using an extremely perseverative card selection strategy, $X^2(1, N=50)=5.98$, $p<0.05$. No other significant effects were found.

3.1.2. Performance on decision-making under risk

3.1.2.1. Coin flipping task. A repeated measures ANOVA was performed, with group as a between-subjects factor; ratio of potential win/loss (6 ratio) as a within subjects factor; and the participant's acceptance score as the dependent measure. Results of the CFT are presented in Fig. 3. This analysis revealed

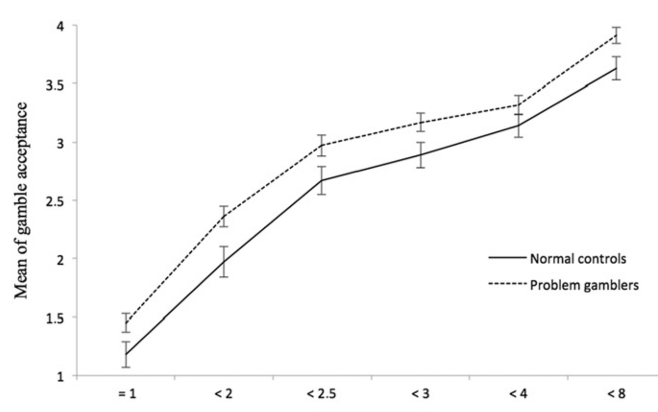

Fig. 3. Means of gamble acceptance according to each combination of gains and losses (WIN/LOSS ratio) by normal controls and problem gamblers.

an effect of ratio, $F(5, 93)=220.24$, $p<0.001$, $\eta^2=0.71$, indicating that risk acceptance of participants increased as much as the difference between potential reward and potential loss increased.

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Importantly, we also observed a main group effect, $F(1, 97)=5.61$, $p<0.05$, $\eta^2=0.06$, indicating that problem gamblers displayed elevated risk acceptance throughout the task, as compared to normal controls.

3.1.2.2. Cups task. We conducted a 3 (EV level: risk advantageous; risk equal; risk disadvantageous) × 2 (Domain: gain or loss) × 2 (Group) repeated measures analysis of variance to compare the groups' risk taking as a function of EV differences between choice options in each domain. Results of the Cups task are presented in Fig. 4. We found a main effect of EV, $F(2, 98)=44.73$, $p<0.001$, $\eta^2=0.31$, indicating more risk taking with higher EV levels; an EV × Domain interaction, $F(2, 98)=48.33$, $p<0.001$, $\eta^2=0.33$, indicating that risk taking is dependent of EV level only for the Gain domain; and an EV × Group interaction, $F(2, 98)=3.72$, $p<0.05$, $\eta^2=0.04$, indicating that, compared with normal controls, problem gamblers displayed elevated risk taking on risk equal EV and risk disadvantageous EV trials for the gain domain and elevated risk taking on risk equal EV trials for the Loss domain (see Fig. 4). Taken together, these results showed that problem gamblers had a higher tendency to take risks on the Cups task, especially in the gain domain.

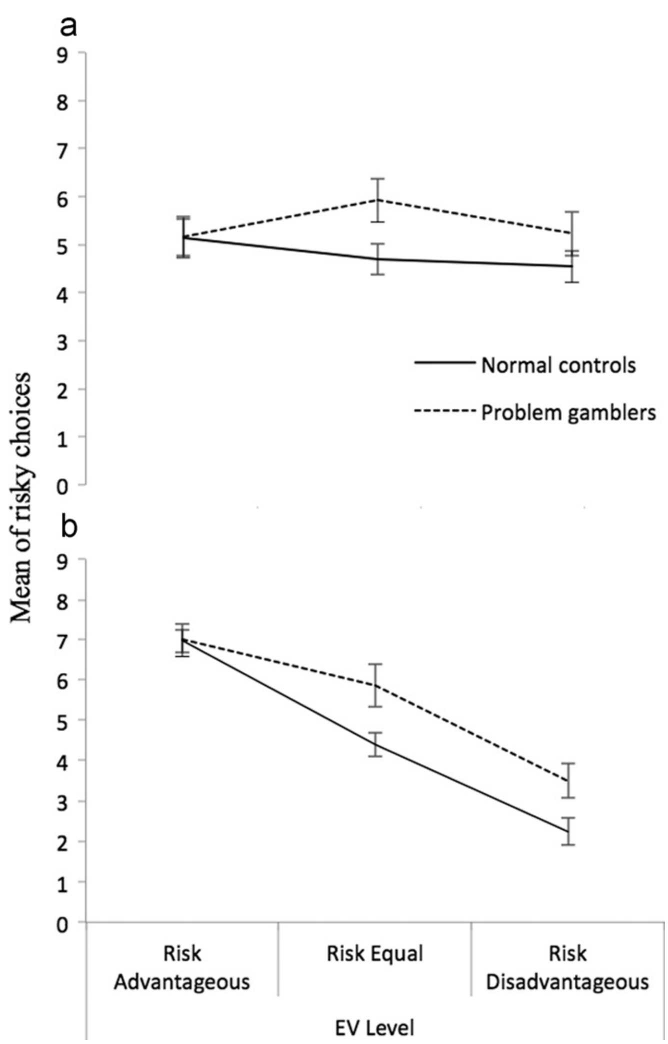

Fig. 4. Means of risky choices in (a) the Loss and (b) the Gain domain, as a function of subject group and Expected-Value (EV) level (Risk Advantageous trials; Risk Equal expected value trials; Risk Disadvantageous trials). Subjects received nine gain trials and nine loss trials for each of the three EV levels.

3.2. Decision-making and gambling dependence severity

Analyses revealed that SOGS scores were negatively correlated with number of advantageous performances on the third ($r=-0.26$, $p<0.05$) and the fourth stage ($r=-0.29$, $p<0.05$) of the IGT.

In order to examine performance on the CPT in function of problem gambling severity, we performed a univariate ANOVA with category of performance on the CPT (optimal; conservative; perseverative; extremely perseverative) as between-subjects factor and mean of the SOGS scores as dependent measure. We found a main effect of category of performance, $F(3, 62)=2.81$, $p<0.05$. Pairwise group comparisons were performed and revealed that problem gamblers who exhibited an extremely perseverative performance on the CPT had higher scores on the SOGS ($M=9.26$, $SD=2.63$) compared to problem gamblers with a perseverative performance ($M=5.86$, $SD=3.64$, $t(29)=4.67$, $p<0.05$).

3.3. Performance on working memory

3.3.1. Operation span task

A one-way ANOVA was performed, with group as a between-subjects factor; and the PCU score as the dependent measure. Results revealed that, compared to problem gamblers ($M=0.71$; $SD=0.18$), controls ($M=0.79$; $SD=0.13$) had a higher score on the Ospan, $F(1, 98)=4.47$, $p<0.05$.

3.3.2. Digit span

Scores were analyzed using a one-way ANOVA, with group as between-subjects factor; and the maximum number of digits correctly recalled, as the dependent measure. There was no difference between normal controls ($M=10.69$; $SD=1.53$) and problem gamblers ($M=10.10$; $SD=2.30$), $F<1$.

3.4. Correlation between working memory and decision-making

We performed correlations between the results on decision-making tasks and scores on the Ospan and the Digit span to determine whether a relationship existed between decision-making and working memory. Correlation analyses were conducted separately for problem gamblers and normal controls. Decision-making performance measures were correlated with Ospan but not with Digit Span performance. Significant correlation between Ospan and decision-making tasks are shown in Table 3.

4. Discussion

The main findings of the present study can be summarized as follows: First, compared to normal controls, problem gamblers were impaired in both decision-making under risk and under

Table 3
Correlations between Ospan score and decision making tasks performances in the normal controls ($n=35$) and problem gamblers ($n=65$).

Controls		*Normal controls*	*Problem gamblers*
IGT	Stage 4	0.41*	−0.09
Cups Task	Risk-advantageous Gain	0.44**	0.33*
	Risk-disadvantageous Gain	−0.43*	−0.4**
	Risk-disadvantageous Loss	−0.31	−0.02
CFT	Ratio Gain/Loss=1	−0.37*	−0.24
	Ratio Gain/Loss < 2	−0.33*	−0.07

* $p<0.05$.
** $p<0.01$.

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ambiguity. Second, problem gamblers were impaired on dual tasking (a main central executive components of working memory), which was correlated with advantageous performance on decision-making under risk. Third, we found a relationship between problem gambling severity and impaired decision-making under ambiguity, but not under risk. These results could not be explained by the intensity of anxiety, depression, as well as ADHD symptoms.

Both the Iowa gambling task (IGT) (and especially the earlier blocks) and the Card Playing Task (CPT) reflect measures of decision-making under ambiguity because the participants do not have knowledge about the probability of the reward outcomes in the task. On the IGT, problem gamblers performed worse than normal controls by selecting more cards from the disadvantageous decks. This result is in line with other studies that showed diminished performance on the IGT in pathological gamblers (e.g., Forbush et al., 2008; Goudriaan et al., 2005) and problem gamblers (Lakey et al., 2007). Interestingly, problem gamblers were also impaired on the CPT by exhibiting a perseverative response profile (for similar findings, see Goudriaan et al. (2005)). Disadvantageous strategies exhibited by problem gamblers on the IGT and the CPT may be explained by altered processes operating mainly on an implicit level (e.g. Bechara, 2003). It might be a diminished ability to generate an emotional response associated with a possible success or a failure to process aversive and/or positive feedback in problem gamblers that results in this performance profile (e.g., Bechara, 2003; Goudriaan et al., 2006).

With regard to decision-making under risk, assessed by the Coin Flipping task (CFT) and the Cups task, problem gamblers were more impaired than normal controls. Indeed, on the CFT, problem gamblers showed a greater acceptance to gamble than normal controls during trials in which potential losses equal potential wins and during trials in which potential losses outweighed potential gains. On the Cups Task, problem gamblers took more risk than normal controls for the risk-equal and risk-disadvantageous conditions of the gain domain. Our findings on decision-making under risk are in line with previous studies (Brand et al., 2005a,b; Labudda et al., 2007), which reported impairment on decision-making under risk in pathological gamblers by using tasks resembling the CFT and the Cups task (e.g., the Game of Dice Task; Brand et al., 2002). Unlike the IGT and the CPT, the CFT and the Cups task provide explicit rules to the participants and thus may rely more on more "cognitive" processes, such as working memory and executive control, in the evaluation of risk. Therefore, risky choices exhibited by problem gamblers on the CFT and the Cups task may be explained by diminished executive supervision (Brand et al., 2007). Indeed, in both the normal control and problem gambler groups, safe and risky choices were, respectively, positively and negatively correlated with dual task (i.e., on the Ospan task) performance (for similar findings see, Brand et al., 2005a,b). Disadvantageous decision-making under risk in problem gamblers might also be due to an inability to generate emotional responses associated with potential choices to process aversive and/or positive feedbacks. For instance, Labudda et al. (2007 found that pathological gamblers who showed less disadvantageous decision-making under risk also showed an increase in sympathetic nervous system activity (i.e., secretion of alpha-amylase) during the task, thus reflecting potential influence of emotion and biases in decision-making under risk.

Importantly, problem gambling severity was correlated with performance in decision-making under ambiguity performance but not with decision-making under risk. The more severe problem gambling is, the more impaired is the decision-making under ambiguity. A possible explanation of this association, which is in line with the somatic marker hypothesis (Damasio, 1994), is that gamblers with impaired anticipatory somatic markers while making a decision could exhibit poor decision-making under ambiguity on the one hand and are therefore also more likely to develop the most severe gambling problems (Bechara and Damasio, 2005). In other terms, intact somatic markers while making a decision under uncertainty could be a protective factor against gambling problems. Supporting this idea, anticipatory psychophysiological reactions to disadvantageous choices during the IGT were lower in pathological gamblers than in normal controls (Goudriaan et al., 2006). Interestingly, impaired somatic markers may have more impact on decisions made under ambiguity than those made under risk (Brand et al., 2006). Indeed, findings indicated that normal subjects generate minimal anticipatory skin conductance responses (SCRs) during decisions under risk (for instance in the "betting" task designed by Rogers et al. (1999)) especially in relation to the most certain choices compared to the most risky choices. Most importantly, the overall average of anticipatory SCRs generated during the "betting" task is lower than SCRs during the ambiguity processing in the IGT. This is consistent with the idea that decision-making under ambiguity, where the outcome is unknown and unpredictable, engages more anticipatory somatic marker activation (for a review of this issue, see Bechara and Damasio, 2005).

This paper has several limitations. First, we cannot isolate the "problem gambling" component per se since pathological gamblers have been compared to a normal control group consisting largely of non-gamblers. This problem limits the generalization of our results. Therefore, it is important to extend this research to a larger sample of gamblers which has both extreme ends of the spectrum of gambling dependence well represented, including healthy non-problem gamblers (e.g., usual lottery players) as well as pathological gamblers with comorbid substance disorders (e.g., alcohol). Moreover, from the existing data on pathological gambling it is not yet clear whether impairments of decision-making are a consequence or a precursor of addictive behaviors. Longitudinal design studies are thus needed in order to investigate if decision-making deficits are a cause and/or a consequence of gambling abuse. Finally, the association between decision-making under ambiguity and gambling dependence severity as observed in this study, raises questions regarding the emotion-related basis for these deficits. It would therefore be advisable to use psychophysiological measures in order to test directly the hypothesis of the association between decision-making and gambling dependence severity. Altogether, such research might clarify the precise nature of the relationship between gambling dependence severity and impairments on decision-making processes, given that these mechanisms are proposed to play a key role in maintaining addictive behaviors.

In summary, problem gamblers were impaired in making their decisions under risk and under ambiguity, with an impaired executive component of working memory associated only with risk taking. The fact that decision-making under ambiguity was not related to working memory performance, suggests that executive function components cannot explain the diminished performance under ambiguity in problem gamblers. The severity of gambling addiction was associated only with decision under ambiguity, which may indicate disrupted basic emotional processing (i.e., anticipatory somatic marker activation) in problem gamblers influencing their decision-making regarding gambling disadvantageously.

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References

Bechara, A., 2003. Risky business: emotion, decision-making, and addiction. Journal of Gambling Studies 19, 23–51.
Bechara, A., 2005. Decision-making, impulse control and loss of willpower to resist drugs: a neurocognitive perspective. Nature Neuroscience 8, 1458–1463.
Bechara, A., Damasio, A.R., 2005. The somatic marker hypothesis: a neural theory of economic decision. Games and Economic Behavior 52, 336–372.
Bechara, A., Damasio, A.R., Damasio, H., Anderson, S.W., 1994. Insensitivity to future consequences following damage to human prefrontal cortex. Cognition 50, 7–15.
Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 1997. Deciding advantageously before knowing the advantageous strategy. Science 275, 1293–1294.
Beck, A.T., Ward, C.H., Mendelson, M., Mock, J., Erbaugh, J., 1961. An inventory for measuring depression. Archives of General Psychiatry 4, 561–571.
Brand, M., Fujiwara, E., Borsutzky, S., Kalbe, E., Kessler, J., Markowitsch, H.J., 2005a. Decision-making deficits of korsakoff patients in a new gambling task with explicit rules: associations with executive functions. Neuropsychology 19, 267–277.
Brand, M., Kalbe, E., Labudda, K., Fujiwara, E., Kessler, J., Markowitsch, H.J., 2005b. Decision-making impairments in patients with pathological gambling. Psychiatry Research 133, 91–99.
Brand, M., Greco, R., Schuster, A., Kalbe, E., Fujiwara, E., Markowitsch, H.J., Kessler, J., 2002. The game of dice—a new test for the assessment of risktaking behavior. Neurorehabilitation & Neural Repair 16, 142–143.
Brand, M., Labudda, K., Markowitsch, H.J., 2006. Neuropsychological correlates of decision-making in ambiguous and risky situations. Neural Networks 19, 1266–1276.
Brand, M., Recknor, E.C., Grabenhorst, F., Bechara, A., 2007. Decisions under ambiguity and decisions under risk: correlations with executive functions and comparisons of two different gambling tasks with implicit and explicit rules. Journal of Clinical Experimental Neuropsychology 29, 86–99.
Conway, A.R., Kane, M.J., Bunting, M.F., Hambrick, D.Z., Wilhelm, O., Engle, R.W., 2005. Working memory span tasks: a methodological review and user's guide. Psychonomic Bulletin Review 12, 769–786.
Damasio, A., 1994. Descartes' error: emotions, reason, and the human brain. Avon Books, New York.
Forbush, K.T., Shaw, M., Graeber, M.A., Hovick, L., Meyer, V.J., Moser, D.J., Bayless, J., Watson, D., Black, D.W., 2008. Neuropsychological characteristics and personality traits in pathological gambling. CNS Spectrum 13, 306–315.
Goudriaan, A.E., Oosterlaan, J., de Beurs, E., van den Brink, W., 2004. Pathological gambling: a comprehensive review of biobehavioral findings. Neuroscience Biobehavrioral Review 28, 123–141.
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.
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 Alcohol Depend 84, 231–239.
Goudriaan, A.E., Oosterlaan, J., de Beurs, E., van den Brink, W., 2008. The role of self reported impulsivity and reward sensitivity versus neurocognitive measures of disinhibition and decision-making in the prediction of relapse in pathological gamblers. Psychological Medecine 38, 41–50.
Groth-Marnat, G., 1997. Handbook of Psychological Assessment, 3rd ed. John Wiley & Sons, New York.
INSERM, 2008. Expertise collective: Jeux de hasard et d'argent, contexte et addiction (Collective expert report: gambling, context and addiction). INSERM, Paris.
Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263–292.
Kessler, R.C., Adler, L., Ames, M., Delmer, O., Faraone, S., Hiripi, E., Howes, M., 2005. The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. Psychological Medecine 35, 245–256.
Lakey, C.E., Goodie, A.S., Campbell, W.K., 2007. Frequent card playing and pathological gambling: the utility of the Georgia gambling task and Iowa gambling task for predicting pathology. Journal of Gambling Studies 23, 285–297.
Labudda, K., Wolf, O.T., Markowitsch, H.J., Brand, M., 2007. Decision-making and neuroendocrine responses in pathological gamblers. Psychiatry Research 153, 233–243.
Lawrence, A.J., Luty, J., Bogdan, N.A., Sahakian, B.J., Clark, L., 2009. Impulsivity and response inhibition in alcohol dependence and problem gambling. Psychopharmacology 207, 163–172.
Lesieur, H.R., Blume, S.B., 1987. The South Oaks Gambling Screen (SOGS): a new instrument for the identification of pathological gamblers. American Journal of Psychiatry 144, 1184–1188.
Levin, I., Weller, J., Pederson, A., Harshman, L., 2007. Age-related differences in adaptive decision-making: sensitivity to expected value in risky choice. Judgment Decision-Making 2, 225–233.
McLellan, A.T., Kushner, H., Metzger, D., Peters, R., Smith, I., Grissom, G., Pettinati, H., Argeriou, M., 1992. The fifth edition of the addiction severity index. Journal of Substance Abuse Treatment 9, 199–213.
Newman, J.P., Patterson, C.M., Kosson, D.S., 1987. Response perseveration in psychopaths. Journal of Abnormal Psychology 96, 145–148.
Roca, M., Torralva, T., Lopez, P., Cetkovich, M., Clark, L., Manes, F., 2008. Executive functions in pathologic gamblers selected in an ecologic setting. Cognitive Behavioral Neurology 21, 1–4.
Rogers, R.D., Owen, A.M., Middleton, H.C., Williams, E.J., Pickard, J.D., Sahakian, B.J., Robbins, T.W., 1999. Choosing between small, likely rewards and large, unlikely rewards activates inferior and orbital prefrontal cortex. Journal of Neuroscienscе 20, 9029–9038.
Spielberger, C., 1983. Manual for the State-Trait Anxiety Inventory: STAI (Eorm I). Consulting Psychologists Press, Palo Alto, CA.
Starcke, K., Pawlikowski, M., Wolf, O.T., Altstötter-Gleich, C., Brand, M., et al., 2011. Decision-making under risk conditions is susceptible to interference by a secondary executive task. Cognitive Processing 12, 177–182.
Starcke, K., Tuschen-Caffier, B., Markowitsch, H.J., Brand, M., 2010. Dissociation of decisions in ambiguous and risky situations in obsessive–compulsive disorder. Psychiatry Research 177, 114–120.
Tom, S.M., Fox, C.R., Trepel, C., Poldrack, R.A., 2007. The neural basis of loss aversion in decision-making under risk. Science 315, 515–518.
Turner, M.L., Engle, R.W., 1989. Is working memory capacity task dependent? Journal of Memory and Language 28, 127–154.
van Holst, R.J., van den Brink, W., Veltman, D.J., Goudriaan, A.E., 2010. Why gamblers fail to win: a review of cognitive and neuroimaging findings in pathological gambling. Neuroscience Biobehavioral Review 34, 87–107.
Wechsler, D., 2000. WAIS-III. Échelle d'intelligence de Wechsler pour adultes, Troisième édition. ECPA, Paris.
Weller, J.A., Levin, I.P., Shiv, B., Bechara, A., 2007. Neural correlates of adaptive decision-making for risky gains and losses. Psychological Science 18, 958–964.