ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

Impaired Decision-Making Under Risk in Individuals with Alcohol Dependence

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Background: Alcohol dependence is associated with poor decision-making under ambiguity, that is, when decisions are to be made in the absence of known probabilities of reward and loss. However, little is known regarding decisions made by individuals with alcohol dependence in the context of known probabilities (decision under risk). In this study, we investigated the relative contribution of these distinct aspects of decision-making to alcohol dependence.

Methods: Thirty recently detoxified and sober asymptomatic alcohol-dependent individuals and 30 healthy control participants were tested for decision-making under ambiguity (using the Iowa Gambling Task[IGT]) and decision-making under risk (using the Cups Task and Coin Flipping Task). We also tested their capacities for working memory storage (digit span forward) and dual tasking (operation span task).

Results: Compared to healthy control participants, alcohol-dependent individuals made disadvantageous decisions on the IGT, reflecting poor decisions under ambiguity. They also made more risky choices on the Cups and Coin Flipping Tasks reflecting poor decision-making under risk. In addition, alcohol-dependent participants showed some working memory impairments, as measured by the dual tasking, and the degree of this impairment correlated with high-risk decision-making, thus suggesting a relationship between processes subserving working memory and risky decisions.

Conclusions: These results suggest that alcohol-dependent individuals are impaired in their ability to decide optimally in multiple facets of uncertainty (i.e., both risk and ambiguity) and that at least some aspects of these deficits are linked to poor working memory processes.

Key Words: Addiction, Alcohol, Decision-Making, Ambiguity, Risk, Working Memory.

ALCOHOL-dependent individuals exhibit poor decision-making as reflected by their continued alcohol use despite encountering problems directly linked to these drinking habits (American Psychiatric Association, 2013). This aberrant profile of decision-making has been further evidenced in laboratory settings, through, for instance, the use of the Iowa Gambling Task (IGT; Bechara et al., 1994). A key feature of the IGT is that participants have to forgo short-term benefits for long-term benefits, a process that is presumably severely hampered in substance (e.g., drugs, alcohol, tobacco) and nonsubstance addictions (e.g., gambling) (Noël et al., 2013). For instance, a high proportion of alcohol-dependent patients detoxified and abstinent from alcohol for a few weeks (e.g., Kornreich et al., 2013; Noël et al., 2007) or even for several years (Fein et al., 2004) make more choices than healthy participants that bring immediate reward, but then lead to more severe delayed punishment. These findings highlight that impaired decision-making process measured by the IGT does not recover over time, that is, after abstinence from using alcohol and may impact on the risk of relapse even after months and years.

One limitation of these findings is that they cannot be generalized to the general spectrum of situations of decision-making under uncertainty. Indeed, depending on the quality of information available for elaborating a decision, decisional context could be totally ambiguous because of the absence of any useful information to anticipate a given outcome or a risk could be estimated, because of either provided to the decision-maker (e.g., 1 chance in 2 to win) or calculated through practice (e.g., Kahneman and Tversky, 1979). The IGT represents a complex task, for which a number of cognitive and affective processes are involved (e.g., working memory, episodic memory, inhibition, mental flexibility, automatic emotional activation during the deliberation phase; Dunn et al., 2006). Even though, in the latter trials of the IGT (e.g., from trials 60 to 100; Brand et al., 2006; Brevers et al., 2012), the subject may acquire some sense of the probabilities of reward and loss, thus requiring mental calculation and working memory, the knowledge of these probabilities is not explicit and remains largely unknown

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(notion of ambiguity), thus requiring a decision-maker to rely more on intuition and emotion than on the logic (Bechara et al., 1997). Other tasks are more direct measures of risk taking because probabilities of reward and loss are simply given to the participant (e.g., the Cups Task [Levin et al., 2007]; the Coin Flipping Task [Tom et al., 2007]). So far, only 1 study has examined decision-making under risk in alcohol-dependent individual (Bowden-Jones et al., 2005) using the Cambridge Gambling Task (Rogers et al., 1999), which provides choices with explicit probabilities of risk, that is, it measures decisions under risk. The study found alcohol-dependent individuals exhibit a stubborn preference for options featuring high but uncertain rewards instead of options featuring lower but certain rewards (Bowden-Jones et al., 2005).

In light of the limited research, further studies were needed to provide a close contrast between impairments of decision-making under ambiguity and under risk in alcohol dependence, as both situations decision-making under risk account for poor decision-making outside of the laboratory. As an example of decision-making under risk, an alcohol-dependent individual has to reach a metro-station and has to choose between a short-length walk but with plenty of alcohol-liquor stores throughout (low physical effort but high risk of relapse) or a longer but "alcohol-safe" path. As an example of decision-making under ambiguity, an alcohol-dependent individual has to decide whether to go or not to a party, he has to take into account that he want to meet his friends (who are supportive with regard to his alcohol problem) but that he also *might* have to resist to different alcohol proposals made by individuals who are not aware of his alcohol problem.

In addition, based on this theoretical distinction and on the literature showing that alcohol-dependent individuals exhibit a number of cognitive impairments affecting distinct domains of executive functioning (for a review, see Noël et al., 2010), a number of hypotheses could be put forward. Indeed, deteriorations in emotional and/or rational processes could alter decision-making differently. For instance, because it does not offer explicit rules on probabilities, decision-making under ambiguity has to be made through the reactivation of previous experiences of rewards and losses (Brand et al., 2006; Krain et al., 2006). By contrast, making a decision under risk, which offers explicit rules for reinforcement and punishment, would involve both the integration of prechoice emotional processes and rational analytical system aspects that require the capacity to represent a dilemma, maintain and organize information in working memory, strategically plan and execute a response, and to evaluate the efficacy of the solution (Brand et al., 2006; Krain et al., 2006). This idea is supported by data showing that advantageous decision-making under risk (Starcke et al., 2011), but not under ambiguity (Turnbull et al., 2005), is lowered when subjects have to take a decision while concurrently performing a secondary task (random number generation), which is known to load on executive resources (Baddeley and Della Sala, 1996). Neuroimaging data also support this distinction. Indeed, on the one hand, decision-making under ambiguity and under risk may be associated with activity in the orbitofrontal and the ventromedial prefrontal cortex with regard to the use of feedback to improve decision-making (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 (Brand et al., 2006). These regions are critical for the exercise of executive control (Kerr and Zelazo, 2004; Starcke et al., 2011), which is also considered a specific process of working memory (Baddeley and Della Sala, 1996).

Importantly, neuropsychological studies have repeatedly highlighted that alcohol dependence is associated with impaired executive functioning, including working memory, planning, and flexibility (e.g., Blume et al., 2005; Dao-Castellana et al., 1998; Noël et al., 2001). These disorders constrain the possibilities of flexible changes of action strategies, reduce behavior control and suppress psychosocial adaptation abilities, which might in turn impair decision-making under risk.

The aim of this study was to examine the capacity of alcohol-dependent individuals to make decisions under risk and under ambiguity. We hypothesized that, as compared with healthy controls, alcohol-dependent individuals exhibit a disadvantageous decision-making profile in both decision-making under risk and under ambiguity. In addition, we hypothesized that advantageous decision-making under risk is associated with the capacity to maintain and organize information in working memory (as an estimation of executive processes), for which alcohol-dependent individuals are impaired.

MATERIALS AND METHODS

Participants and Recruitment

Thirty recently detoxified alcoholic and 30 healthy controls participated in the study. All subjects were adults (>18 years old).

Alcohol-dependent participants were recruited for this study from the Alcohol Detoxification Program of the Psychiatric Institute, Brugmann Hospital, Free University of Brussels, Brussels, Belgium. Participants had to meet Diagnostic and Statistical Manual of Mental Disorders (4th ed.; DSM-IV; American Psychiatric Association, 1994) criteria for alcohol dependence (made by Paul Verbanck, a board-certified psychiatrist). Reasons for exclusion were other current DSM-IV Axis I diagnoses, a history of significant medical illness, head injury resulting in a loss of consciousness for longer than 30 minutes that might have affected the central nervous system, use of other psychotropic drugs or substances that influence cognition, and overt cognitive dysfunction. Subjects were examined after they had abstained from alcohol for a minimum of 18 days and at least 5 days after a standard detoxification period. The detoxification regimen consisted of B vitamins and decreasing doses of sedative medication (diazepam). All received complete medical, neurological, and psychiatric evaluations prior to enrollment in the study.

Participants from the control group were recruited by word of mouth from the community. Before being enrolled in the study, controls were first asked to complete a brief prescreening tool estimating drug and alcohol use. Control participants were excluded if they reported to consume drugs within the past 12 months. With regard to alcohol consumption, controls were asked: (i) to estimate the maximum consecutive number of days they had consumed an alcohol beverage within the past 10 years; (ii) to estimate the average quantity per days consumed; and (iii) to report the type of alcohol beverage. Quantity and type of alcohol beverage were indexed with pictures (i.e., half pint of beers; half pint of strong beers; 175 ml glass of wine; 25 ml glass of spirit; 275 ml bottle of alcopops). We excluded subjects who consumed more than 54 g/d of alcohol (i.e., 4 half pints of beers; 2 half pints of strong beers; two 175 ml glasses of wine; three 25 ml glasses of spirit; three 275 ml bottles of alcopops) for longer than 30 days.

Current Clinical Status

Current clinical status was rated with the Beck Depression Inventory (Beck et al., 1961) and the Spielberger State–Trait Anxiety Inventory (STAI; Spielberger, 1983). The number of cigarettes per day was also included to control from some nicotine effects on cognitive processing (e.g., sustained attention; Heishman, 1998).

Decision-Making Tasks

Decision-Making Under Ambiguity: The Iowa Gambling Task. Because this task does not provide any information about the probabilities of reward or loss, nor the value of a given reward or loss, it is thought that this task taxes primarily the process of decision-making under ambiguity (Bechara et al., 1994). In the IGT, participants sat in front of 4 decks of cards that were identical in appearance, except for their labels A, B, C, and D. They were told that the game involved a long series of pack selections and wagers and that the goal was to earn as much money as possible. Participants were informed that each trial would consist of (i) a pack selection and (ii) the turning over of 1 card from the selected pack 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 decks A or B was a loss of 5 times the average per 10 cards (referred to as disadvantageous decks), and the net outcome of choosing from either decks C or D was a gain of 5 times the average per 10 cards (referred to as advantageous decks). The total number of trials was set at 100 card selections. The dependent measure for advantageous choice was the number of cards picked from the advantageous decks in each block of 20 cards.

Decision-Making Under Risk: The Coin Flipping Task. This task is an adaptation of a decision-making task developed by Tom and colleagues (2007), and it was used in this study to examine decision-making under risk with fixed probabilities. Participants decided whether to accept or reject mixed gambles that offered a 50/50 chance of either gaining a given amount of money or losing another amount. To encourage participants to reflect on the subjective attractiveness of each gamble rather than to rely on a fixed decision rule, we asked them to indicate 1 of 4 responses to each gamble (strongly accept, weakly accept, weakly reject, and strongly reject). The size of the potential gain and loss was manipulated independently, with gains ranging from €10 to €40 (in increments of €2) and losses ranging from €5 to €20 (in increments of €1), resulting in 256 random trials. The dependent measure of the Coin Flipping Task was the participant's gamble acceptance for 6 computed win/loss ratio that include trials in which (i) potential gain equal the potential loss, trials where potential gain was maximum (ii) twice, (iii) twice point 5, (iv) thrice, (v) 4 times, or (vi) 8 times the amount of the potential loss. These ranges were chosen because previous studies indicate that people are, on average, roughly twice as sensitive to losses as to gains (i.e., loss aversion; Kahneman and Tversky, 1979). Thus, we expected that this range of gambles would elicit a wide range of attitudes, from strong acceptance to indifference to strong rejection.

The Cups Task. This task investigates decision-making under risk with both known probability and known value of reward and loss (Levin et al., 2007). 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 1 side of the screen, with the possible gain or loss shown on top. This array is identified as the risky side where selection of 1 cup 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 2 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 3 EV level (risk-advantageous, risk-equal, risk-disadvantageous; see Table 1) for both the Gain and the Loss domains.

Working Memory

Working memory was assessed using 2 tasks: (i) the digit span task (forward), which is a widely used neuropsychological test that quickly evaluates working memory capacity by determining the maximum length of numbers that participants can serially recall; and (ii) the operation span task (Ospan; Turner and Engle, 1989), which is a dual tasking 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 (PCU) scoring procedure (Conway et al., 2005).

Table 1. Expected Value (EV) for the Risky Option on Gain and Loss Domains of the Cups Task According to Probability Level (p) and Amount (in Euros)

	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

Procedure

The ethical review board of the Brugmann Hospital approved the study, and written informed consent was obtained from all participants. Participants were tested individually in a quiet room, located at the Medical Psychology Laboratory, Brugmann Hospital. The order of test presentation was counterbalanced. No significant correlations between administration order and performance were present. Participants received €20 for their participation. Controls were asked to avoid alcohol consumption for the prior 24 hours.

RESULTS

Demographics and Current Clinical Status

A description of demographic variables and current clinical status is presented in Table 2. The alcohol and the control were similar in terms of age and years of education. Chi-square analyses revealed no differences in the distribution of male and female participants and the distribution of level of education. Depression was higher in alcohol-dependent individuals than in controls, $t(59) = -6.99$, $p < 0.001$.

Table 2. Demographical Data and Standard Deviations for Normal Controls and Alcohol-Dependent Participants

	Control $n = 30$	Alcohol $n = 30$	Test statistics
Age (SD)	41.53 (10.21)	44.48 (11.69)	$t(59) = -1.03$, *ns*
Male/female	24/6	22/8	χ^2 (1,60) = 0.37, *ns*
Education % (*n*)			
Vocational degree	6.6 (2)	16.6 (5)	χ^2 (1,60) = 3.38, *ns*
High-school degree	3.3 (1)	9.9 (3)	
Bachelor degree	70.0 (21)	63.3 (19)	
Master degree	20.0 (6)	10.0 (3)	
Education (years)	15.10 (2.16)	14.06 (2.63)	$t(59) = 1.66$, *ns*
Employed full time% (*n*)	83.3 (25)	50.0 (15)	χ^2 (1,60) = 7.50, $p < 0.01$
BDI	2.13 (2.49)	10.50 (6.06)	$t(59) = -6.99$, $p < 0.001$
STAI-E	30.20 (9.48)	37.57 (13.88)	$t(59) = -2.40$, $p < 0.05$
STAI-T	35.97 (7.41)	45.03 (10.32)	$t(58) = -3.89$, $p < 0.001$
Cigarettes per day	1.74 (5.96)	13.36 (16.86)	$t(54) = -3.43$, $p < 0.01$
Alcohol drink per day	0.94 (1.17)	15.13 (4.56)	$t(59) = -10.59$, $p < 0.001$
Abstinence (day)		22.07 (3.49)	
Alcohol dependence duration (year)		19.57 (7.17)	
Number of times entering an alcohol detoxification program		2.31 (1.67)	

BDI, Beck Depression Inventory; STAI-E, State version of the State-Trait Anxiety Inventory; STAI-T, Trait version of the State-Trait Anxiety Inventory; Alcohol drink per day, average number of alcohol drink per day during the past 12 months (alcohol group: 12 months before entering the detoxification program; control group: 12 months before participating to the study).

Values shown are the mean and standard deviations on each measure. Degrees of freedom differ due to missing data.

Compared with controls, state and trait anxiety was higher in the alcohol group, $t(59) = -2.40$, $p < 0.05$; $t(58) = -3.89$, $p < 0.001$, respectively. The average number of cigarettes smoked per day was higher in alcohol-dependent individuals than in controls, $t(54) = -3.43$, $p < 0.01$. Importantly, we observed no significant correlation between current clinical status (depression, state and trait anxiety, cigarettes per day) and performances on decision-making and working memory tasks. Moreover, chi-square and correlation analyses showed that age, sex, level of education (types and years) had no significant impact on performances on decision-making and working memory tasks (all $p > 0.05$).

Performance on Decision-Making Under Ambiguity: Iowa Gambling Task

A repeated-measures analysis of variance (ANOVA) was performed, with group (control vs. alcohol) as a between-subjects factor; block (5 blocks of 20 trials) as a within-subjects factor; and the net score of advantageous choice (C + D), as the dependent measure. This analysis revealed a group effect, group $F(1, 59) = 4.64$, $p < 0.05$, $\eta^2 = 0.07$, indicating that the control group performed better than the alcohol group; and a Group × Block interaction, $F(4, 56) = 8.88$, $p < 0.001$, $\eta^2 = 0.13$, indicating that task performance increased over time in the control but not in the alcohol group and that controls performed better than alcohol-dependent participants on stages 3, 4, and 5 of the IGT (see Fig. 1).

Performance on Decision-Making Under Risk: Coin Flipping Task

A repeated-measures ANOVA was performed, with group as the between-subjects factor; ratio of potential win/loss

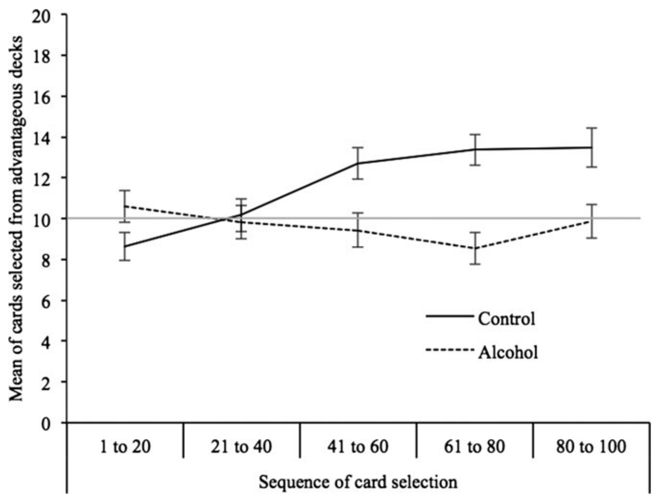

Fig. 1. Means of the total number of cards selected from the advantageous decks for each stage of 20 card choices on the Iowa Gambling Task by the control and the alcohol groups, with 10 indicating no preference for advantageous or disadvantageous decks. Error bars are the standard errors of the mean.

(6 ratio) as the within-subjects factor; and the participant's acceptance score, as the dependent measure. Results of the Coin Flipping Task are presented in Fig. 2. This analysis revealed an effect of ratio, $F(5, 55) = 92.02$, $p < 0.001$, $\eta^2 = 0.61$, indicating that risk acceptance is dependent of ratio of potential win/loss; and a Group × Win/loss ratio interaction, $F(5, 55) = 4.26$, $p < 0.01$, $\eta^2 = 0.07$, indicating that, compared with controls, alcohol-dependent participants displayed elevated acceptance to gamble for trials in which potential gain equals the potential loss, and trials in which potential gain was maximum 2 or 2.5 times the amount of the potential loss (see Fig. 2).

Performance on Decision-Making Under Risk: Cups Task

We conducted a 3 (EV level) × 2 (domain: gain or loss) × 3 (group) repeated-measures ANOVAs 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. 3. We found a main effect of EV, $F(2, 58) = 96.68$, $p < 0.001$, $\eta^2 = 0.63$, indicating that risk taking is dependent of EV level; a main effect of domain, $F(2, 58) = 4.69$, $p = 0.05$, $\eta^2 = 0.08$, indicating that risk taking is lower in the Loss domain; and a main group effect, $F(1, 59) = 4.83$, $p < 0.05$, $\eta^2 = 0.08$, indicating that alcohol-dependent participants displayed elevated risk taking as compared with controls. Additional pairwise comparison revealed that alcohol-dependent individuals took more risk than controls on the risk-equal and risk-disadvantageous conditions of the Gain domain only (see Fig. 3).

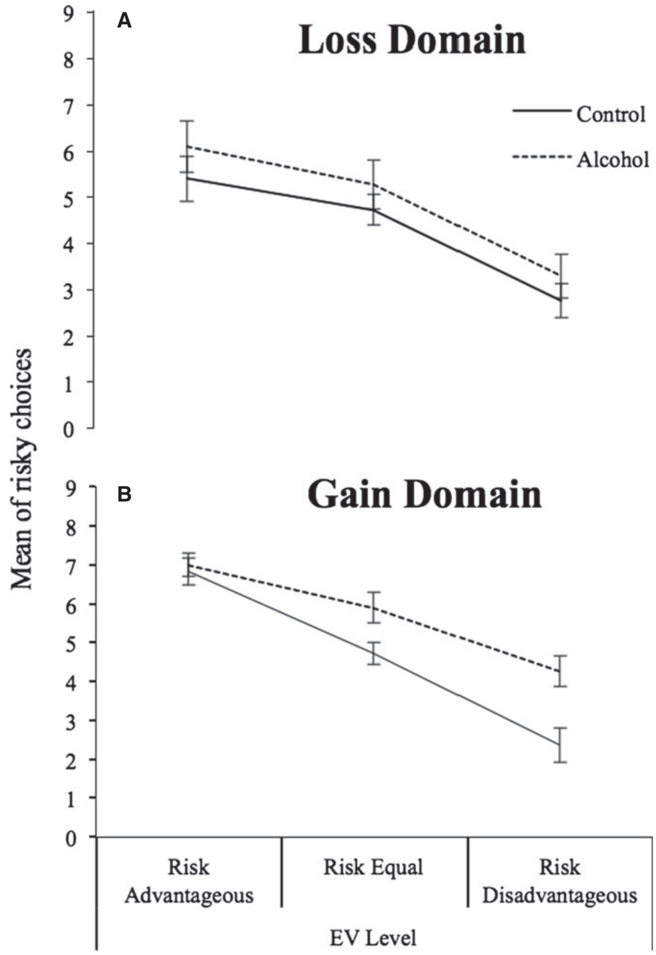

Fig. 3. Means of risky choices in (**A**) the Loss and (**B**) the Gain domain, as a function of subject group (alcohol; control) and expected value (EV) level (Risk-Advantageous trials; Risk-Equal EV trials; Risk-Disadvantageous trials). Subjects received 9 gain trials and 9 loss trials for each of the 3 EV levels.

Performance on Working Memory

The alcohol group ($M = 11.28$, SD = 1.72) did not differ from the control group ($M = 10.76$, SD = 1.56), in terms of maximum length of numbers serially recalled on the digit span task (forward), $t(57) = -1.20$, $p > 0.05$. On the Ospan task, control participants ($M = 0.79$, SD = 0.13) obtained significantly higher PCU scores than alcohol-dependent participants ($M = 0.55$, SD = 0.25), $t(59) = 4.70$, $p < 0.001$. In other words, alcohol-dependent individuals were impaired on dual tasking (i.e., Ospan), but not on verbal storage (i.e., digit span task).

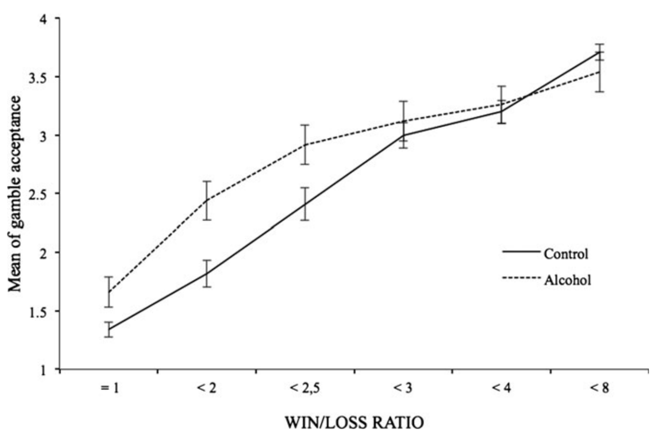

Fig. 2. Means of gamble acceptance according to each combination of gains and losses (win/loss ratio) by controls and alcohol-dependent participants.

Correlations Between Decision-Making and Working Memory

We performed correlations between the results of the decision-making tasks and working memory (maximum length of numbers serially recalled on the digit span task; Ospan PCU scores) to determine whether a relationship existed between working memory functioning and decision-making. Separate correlation analyses were conducted for the alcohol-dependence ($n = 30$) and the control ($n = 30$) groups. In the control group, performance on the Ospan task was negatively correlated with risky choices during the risk-disadvantageous conditions of the Cups Task for the Gain domain only, $r(30) = -0.41$, $p < 0.05$. We also observed significant correlations between the last 2 blocks of IGT trials (from trials 61 to 80 and from trials 81 to 100) and performance on the Ospan, $r(30) = 0.41$, $p < 0.05$, $r(30) = 0.37$, $p < 0.05$, respectively. In the alcohol-dependence group, performance on the Ospan task was negatively correlated with risky choices during the risk-disadvantageous conditions of the Cups Task for both the Loss and Gain domains, $r(30) = -0.40, p < 0.05, r(30) = -0.42, p < 0.05$, respectively. No other significant correlation was observed.

DISCUSSION

This study was the first to examine the quality of decision-making under varying levels of uncertainty (i.e., ranging from decision-making under ambiguity to decision-making under risk) in alcohol-dependent individuals. The key findings of the present study are as follows: First, compared to healthy controls, alcohol-dependent participants exhibited disadvantageous decision-making under ambiguity, and they choose more risky options that led to negative outcomes during decision-making under risk. Second, alcohol-dependent individuals were impaired on dual tasking as reflected by poor scores on the Ospan task, and these scores correlated with high-risk decision-making.

In the present study, the capacity of decision-making under risk was estimated with the Coin Flipping Task (Tom et al., 2007) and the Cups Task (Levin et al., 2007). We observed that alcohol-dependent individuals took more risky decisions than healthy controls on these 2 tasks. More specifically, on the Coin Flipping Task, alcohol-dependent participants showed a greater acceptance to gamble than healthy controls under high-risk trials, that is, when the potential gain equals the potential loss and when the gain was maximum 2 or 2.5 times the amount of the potential loss. In a similar way, on the Cups Task, alcohol-dependent individuals took more risk than controls on the risk-equal and risk-disadvantageous conditions of the Gain domain, that is, in situations characterized by low or moderate rewards EV. These results suggest that individuals suffering from an addiction to alcohol are more prone to take risky choice than controls in high-risk situations. Importantly, between-groups differences were found on the Gain, but not the Loss domain of the Cups Task, which suggests that loss sensitivity is not impaired in alcohol-dependent individuals.

In the alcohol-dependence group, risk taking during the risk-disadvantageous conditions of the Cups Task (for both the Loss and Gain domains) was negatively correlated with performance on the Ospan task, for which alcohol-dependent participants were impaired. In other words, alcohol-dependents' impairment in both storing and manipulating information in working memory is associated with high-risk decision-making. These results are in line with previous findings showing that advantageous decision-making under risk is associated with intact executive processes (Brand, 2008; Brand et al., 2009; Brevers et al., 2012; Starcke et al., 2011). One possible explanation for this result is that a larger working memory processing capacity may facilitate attention shifting during decision-making from more salient rewards (e.g., option featuring high but uncertain reward during the Cups Task) to less salient/risky outcomes (e.g., option featuring low but certain reward during the Cups Task) (Finn, 2002; Finn and Hall, 2004; Oberauer, 2002). Indeed, because lower salient information is more difficult to retain in working memory, those with a high working memory capacity could more easily retain both high and lower salient information in mind, while those with low working memory capacity have greater difficulty retaining low salient information (Finn, 2002; Finn et al., 2002; Hinson et al., 2003). Hence, alcohol-dependent individuals may be more prone to taking high-risk choices because of their lowered capacity to manage the interference effects induced by immediate, highly salient information in working memory. Notably, we did not observe a significant relationship between the Ospan and the Coin Flipping Task. One explanation is that the Coin Flipping Task may be less demanding on working memory than the Cups Task. Indeed, the Cups Task involves options featuring both changing win/loss ratios and win/loss probabilities, whereas the Coin Flipping Task involves options featuring changing win/loss ratios but a fixed 50/50 probability.

With regard to decision-making under ambiguity, we observed that the alcohol-dependent group choose more often disadvantageous decks than advantageous decks throughout the IGT, that is, they preferred options that bring immediate reward, but then lead to more severe delayed punishment. This result is in line with previous studies showing that recently detoxified alcohol-dependent individuals display an aberrant profile of decision-making on the IGT (e.g., Mazas et al., 2000; Noël et al., 2007). Interestingly, in healthy controls, we observed a correlation between the last 2 blocks of IGT trials (from trials 60 to 100) and performance on the Ospan. This result seems surprising when referred to the literature advancing that the IGT taps essentially into emotional processes, that is, aspects of decision-making that are predominately influenced by affect and emotion (e.g., Bechara et al., 1994, 1997, 2000). Nevertheless, several recent findings suggest that not all aspects of the IGT are equal at detecting "emotional" decision-making processes. Consistent with this view, performances on working memory (e.g., Brevers et al., 2012) and cognitive flexibility (Brand et al., 2007; Iudicello et al., 2013) have been associated with performance of healthy controls in the latter stages of the IGT. Hence, these results suggest that executive processes may be involved in the latter trials of the IGT. One explanation for these findings is that, across trials, the IGT may vary according to its level of uncertainty (Brand et al., 2006). More specifically, selections during the last block of trials may be referred as decision-making under risk (i.e., situations of decision-making in which probabilities of reward and loss are known) because participants should have experienced the different win/loss contingencies enough to hypothetically know which decks are risky and which are not. By contrast, because there has not been time for a participant to experience any of the win/loss contingencies during early deck choices, the first blocks of the IGT refer to decision-making under ambiguity (i.e., situations of decision-making in which probabilities of reward and loss are unknown). With regard to the alcohol-dependent group, no significant correlation was found between the IGT and the Ospan. These findings suggest that impaired IGT performance in the alcohol-dependent participants is independent from their deficit in working memory. To a broader extent, these results are in line with theoretical accounts, which advance that before elaborate decontextualized problem-solving abilities and other related cognitive skills can begin to be enacted, the ability to control emotional reactions and inhibit basic behavioral impulses is required first (Barkley, 1997; Giancola et al., 2012; Sonuga-Barke et al., 2002). More specifically, alcohol dependence may be underlined by powerful impulsive motivational-habit machinery directed at high, short-term rewards (e.g., disadvantageous decks on the IGT), which could possibly interfere or "hijack" the top-down reflective mechanisms necessary for triggering alarming signals about future outcomes (Noël et al., 2013a,b; Verdejo-Garcia and Bechara, 2009). Put differently, exaggerate impulsive incentive processes directed at high-uncertain rewards would hamper further elaborated decontextualized problem-solving abilities. Further studies are needed to confirm that impaired executive processes do not impact IGT performance in alcohol-dependent individuals. One option would be to increase the number of IGT trials (e.g., from 100 to 120) and to examine the association between these later trials and several measures of executive function, including working memory, and planning and cognitive flexibility. Additional studies are also needed to better estimate the impact of impulsive incentive process on top-down reflective processes. One direction for future studies would be to measure autonomic arousal during functional magnetic resonance imaging (fMRI) scanning (for a review on how integrating fMRI with psychophysiological measurements during the IGT, see Wong et al., 2011), which would complement behavioral findings in providing a more comprehensive understanding on the physiological and neural mechanisms underlying impaired decision-making in alcohol dependence.

In summary, recently detoxified alcohol-dependent individuals were impaired in making their decisions under risk and under ambiguity, with an impaired executive component of working memory associated only with high-risk decision-making. This study extends our knowledge about impairments of decision-making under uncertainty in alcohol dependence.

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