Response inhibition deficit is involved in poor decision-making under risk in non-amnesic individuals with alcoholism

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Abstract

Introduction

Addiction is characterized by compulsive preoccupation with obtaining their favorite drug despite of devastating consequences affecting social and occupational functioning (e.g., in the area of employment, family, education and health) (American Psychiatry Association, 1994). Why do some individuals continue using their favourite drug while they are experiencing negative consequences?

In human, decision-making has been explored by several laboratory tasks that mimic real life decisions (for a review, see Fellows, 2004). For instance, the Iowa Gambling task (IGT, Bechara et al., 1994) requires individuals to choose between several alternatives. The choices (selection of cards from different decks) are either advantageous or disadvantageous but each choice is full of ambiguity regarding the outcome, because its difficulty for the subject to keep track and remember the gains and losses from previous trials.

In this task, a high proportion of polysubstance-dependent individuals showed below normal level of performance on the IGT, that is to say, they purse actions that bring immediate reward by neglecting delayed negative consequences (e.g., Bechara et al., 2001; Bechara et al., 2002; Bechara and Martin, 2004; Grant et al., 2000; Fishbein et al., 2005). Poor performance in this decision-making task was also found in alcoholics detoxified for a few weeks (Goudriaan et al., 2005) and for several years (Fein et al., 2004) and also in pathological gamblers (Cavedini et al., 2002; Goudriaan et al., 2005), in individuals dependent to cocaine (Bechara et al., 2001; Grant et al., 2000) and in long-term heavy marijuana users (Whitlow et al., 2004). Besides, performance of the IGT was best predicted by a calculation integrating the severity of addiction (e.g., quantity of drug used, number of detoxification treatments) and the ability to hold gainful employment, thus reflecting the ecological pertinence of the IGT (Bechara et al., 2001).

The identification of cognitive processes involved in poor performance in addicts on the IGT remains unclear: different explanations have been put forward. According the somatic marker hypothesis, like patients with brain lesions in the ventromedial cortex, substance addicts would not be correctly assisted by emotions (Damasio et al., 1995; Bechara et al., 1997). Indeed, they would not benefit from bodily states (or brain representation thereof) that corresponds to emotional reactions to possible courses of action, effectively reflecting the goodness or badness of the outcomes associated with each course of action. Results showing that unlike normals, a proportion of substance-dependent individuals failed to generate anticipatory skin conductance responses (SCRs) whenever they pondered a choice that turned out to be risky give weight to this explanation (Bechara et al., 2002). An alternative explanation has been that these patients exhibit exaggerated reactions to reward resulting in privileging associated choices (Bechara et al., 2002). As a third explanation, it has been proposed that the IGT is a multi-determined task requiring correct efficiency of working memory, reversal learning/inhibition and rule detection functions (for a review of this question, see Dunn et al., 2006). In support of this hypothesis, Naccache et al. (2005) has reported the results of detailed investigation on a patient called RMB who had suffered damage to left mesio-frontal cortex. RMB showed impaired performance of the IGT despite of intact affective response system, thus suggesting that there can be deficits on the IGT in the absence of deficits in somatic marker generation. Studies showed by the means of dual-task methodologies that performance in the IGT decreases dramatically when participants has to carry out a distracting task (e.g., Hinson et al., 2002), which underlines the contribution of working memory capacities in the IGT. In fact, the relationship between working memory and decision making may be asymmetrical (Bechara et al., 1998). Indeed, when comparing VM patients with patients with damage to dorsolateral prefrontal cortex (known to be involved in working memory) on the IGT and on two tests of working memory, it was shown that working memory did not depend on the intactness of decision-making; participants could have normal working memory in the presence or absence of decision-making impairment but decision-making was compromised by working memory impairment (Bechara et al., 1998). Similar asymmetry dependence between working memory and decision-making has been found in individuals with polysubstance abuse (Bechara and Martin, 2004; Goudriaan et al., 2005). Moreover, IGT acquisition has been found to correlate with resting state activity in the dorsolateral prefrontal cortex, a region known to be activated during working memory tasks (Adinoff et al., 2003).

Another possible mechanism underlying impaired performance of the IGT is the impairment to inhibit dominant response and to reverse learning (Dunn et al., 2006). A crucial aspect of the IGT is that participants have to perform a response reversal; they have to shift their preference away form the decks that are initially rewarding in the first few trials following subsequent punishment. The involvement of response inhibition and shifting functions might be crucial during response selection. Indeed, when faced with a dilemma, once a possible choice has been loaded into working memory and labeled like emotionally positive or negative, it still remains for individuals to perform the response selection (i.e., to reject or to accept the possible choice). This selection is likely to require both response inhibition and shifting. A number of studies have found impaired reversal learning in prefrontal patients (Rolls et al., 1994), indirectly suggesting that this may account for their deficit on the IGT. Fellow and Farah (2003) showed that lesions restricted to ventro-medial prefrontal cortex allow normal acquisition but impaired reversal on simple reversal learning tasks. A recent study (Bechara and Martin, 2004) shown that on a task consisting to withhold a card's color (e.g., red color) while performing a distracting task and then to pick non-matching cards (e.g., black color), polysubstance abusers made more errors than healthy participants and this independently to the duration of the distracting task. This result led the authors to posit that drug abusers exhibit switching and response inhibition deficits rather than storage impairment in working memory. Interestingly, those addicts who performed lower this task obtained lower performance on the IGT, which indirectly suggests that response inhibition is involved in the decision-making task.

Finally, Maia and McClelland (2004) criticized the view of Bechara and colleagues that somatic markers can unconsciously guide advantageous behaviour. By using more sensitive methods, they show that participants have much more knowledge about the game than previously thought. In fact, participants report knowledge of the advantageous strategy more reliably than they behave advantageously. Thus, on the basis of such finding, it is reasonable to hypothesize that the capacity to detect rules may account for IGT performance.

A main limitation of works aiming to identify cognitive functions associated with the IGT is that the beginning and the end of the IGT may require distinct cognitive processes (Bechara et al., 2004; Brand et al., 2006). During approximately the first 40 trials, the decision is likely to be made without knowledge of the possible outcomes or the probabilities for reward and punishment (i.e., decision under ambiguity). Thus, it seems reasonable to infer that cognitive functions belonging to the executive system is not or few involved in a normal level of performance, which may reflect intact implicit affective learning processes (e.g., somatic markers). In contrast, during the last 40 trials, although the possible outcomes are also uncertain, they are described by some probability of each one occurring (i.e., decision under risk). Thus, we expect that executive functions may be required for normal performance.

Taken together, recent findings have led to recognize that distinct executive functions could be involved in decision-making as assessed by the IGT. The aim of the present study was twofold. First, we aimed to replicate recent data showing that when tested after few weeks of alcohol abstinence, detoxified alcoholics are impaired on the IGT. Second, we examined the relative contribution of working memory, pre-potent response inhibition and rule detection to alcoholic's below normal level of performance during the first and the last part of the IGT. It seemed to us still more pertinent with alcoholic patients in view of many findings that decision-making (Goudriaan et al., 2005) and a variety of executive functions hypothesized to be involved in the IGT are disrupted (e.g., Noël et al., 2001; Giancola and Moss, 1998; Moselhy et al., 2001). Indeed, alcoholics abstinent for 2-3 weeks exhibit disadvantageous strategy in the IGT (Goudriaan et al., 2005), deficits of rule detection (Noël et al., 2001), of response inhibition/mental shifting (e.g., Noël et al., 2001; Hildebrandt et al., 2004), of the manipulation of information stored in working memory (e.g., Noël et al., 2001). We here used cognitive tasks that previously shown to discriminate alcoholic than non-alcoholic groups.

Method

Participants

All subjects were adults (> 18 years old) and provided informed consent that was approved by the appropriate human subject committees at the Brugmann Universitary Hospital. The demographic data on the two groups are presented in Table 1.

Abstinent and detoxified alcoholic participants (ALC)

Thirty alcoholic individuals were recruited for this study form the Alcohol Detoxification Program of the Psychiatric Institute, Brugmann Hospital, Brussels, Belgium. They were tested between 18 and 21 days after the drinking cessation. They all received complete medical, neurological, and psychiatric examinations at the time of selection (Table 1). The participants had to meet DSM-IV criteria for alcohol dependence [made by a board-certified psychiatrist (P.V.)]. 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 would have affected the central nervous system, use of other psychotropic drugs or substances that influence cognition, and overt cognitive dysfunction. To increase the reliability of information, alcoholic subjects and their families were interviewed separately. Blood levels of folate, vitamin B12, and B-carotene were measured. The detoxification regimen consisted of B vitamins and decreasing doses of sedative medication (diazepam). Current clinical status was rated using the Montgomery Asberg depression scale (Montgomery and Asberg, 1979) and the Spielberger State Trait Anxiety Inventory (STAI Trait & State; Spielberger, 1993).

Control participants (CONT)

Thirty controls similar for sex, age, and educational level were recruited by word of mouth from healthy community members; they were not paid for their participation. We excluded any who had met an Axis I psychiatric diagnosis assessed by the Structural Clinical Interview for DSM-IV; who had experienced a drug use disorder during the year before enrollment in the study; or who had consumed more than 54g/d of alcohol for longer than 1 month. On the basis of the results of their medical history and physical examination, they were judged to be medically healthy. Controls were asked to avoid the use of drugs, including narcotic pain medication, for the 5 days prior to testing, and to avoid alcohol consumption for the preceding 24 hours.

Procedure

All ALC were inpatients admitted to the Clinic of Addictions for detoxification and treatment. They had serious substance abuse problems requiring professional intervention, which was the reason for their admission.

The duration of their abstinence from substance use was known from the length of their stay at the Clinic of Addictions. The duration varied from one individual to another, but the minimum period was 15 days. Each ALC was tested at the end of treatment, i.e., shortly before discharge. Thus, at the time of testing, the ALC were no longer in acute withdrawal or taking any medication to control withdrawal.

ALC were routinely checked for substance abuse during their treatment. They were also breathalysed and subject to urine toxicology screening for opiates, stimulants and marijuana, immediately before testing. Therefore, we can be reasonably sure that there was no use of substances during the entire period of abstinence.

The Structured Clinical Interview for DSM-IV (SCID-IV) was used to assign Axis I diagnoses (including alcohol and other drug abuse and/or dependence). The duration of abstinence, the number of times in treatment, and the total number of years of abuse were obtained from interviews. Current clinical status was rated using the Montgomery Asberg depression scale (Montgomery and Asberg, 1979) and the Spielberger State Trait Anxiety Inventory (STAI Trait & State; Spielberger, 1993).

Cognitive assessment

All subjects had a neuropsychological examination. All tests were administered in 2 sessions during a 1-day period by a clinical neuropsychologist (XN) specially trained in and familiar with the tests used. The order of presentation was counterbalanced.

Iowa Gambling task (Bechara et al., 1994)

The task involves 4 decks of cards called A', B', C', and D'. In two decks (A'&B'), choosing a card is followed by a high gain of money, but at unpredictable points, the selection of a card is followed by a high penalty, so that in the long run, these decks are disadvantageous. In the other two decks (C'&D'), the immediate gain is smaller but the future loss is also smaller, so that in the long run, these decks are advantageous. More specifically, the schedules of reward and punishment are structured in such a way that the discrepancy between reward and punishment in the disadvantageous decks (A'&B') is rendered larger in the negative direction. That is, the net difference between reward and punishment in each block of 10 cards was set up in such a way that this difference in decks A' and B' increased in the negative direction across each block (i.e. towards larger loss). By contrast, this discrepancy between reward and punishment in the advantageous decks (C'&D') is rendered larger in the positive direction, i.e. this difference in decks C' and D' increased in the positive direction across each block (i.e. towards larger gain). The total number of trials was set at 100 card selections. To score the performance of the subject on the GT, the number of cards picked from decks A' and B' are added in each block of 20 cards, and the number of cards picked from decks C' and D' are added separately in each block of 20 cards. A net score is then obtained by subtracting the total number of cards selected from advantageous minus disadvantageous decks [(C'+D')-(A'+B')] for each block of 20 cards. We also made the distinction between the initial phase of the IGT (the first 40 trials) where subjects learn to make choices, but without having any explicit knowledge about the contingencies in the task that guide their decision (decision under ambiguity) and the latter phase (40 last trials), where and the decisions become more influenced by explicit knowledge about the risks associated with each deck (decision under risk) (Brand et al., in press).

*The Brixton test (*Burgess and Shallice, 1996a)

The Brixton test assesses the capacity to discover and shift logical rules. This test consisted of a series of 56 A4-sized pages that were presented to the subject one at a time. Each page had the same basic template on it: a 2 X 5 array of circles numbered 1 to 10; the only difference between pages was the position of one filled circle. The subject's task of the subject was to predict which circle would be filled on the next page. The correct position could be determined from that on the current page by a simple rule, which changed after between 3 to 8 pages. The experiment involved eight rule changes and six different rules, for example typical ones were to move to the next-lower number (rule –1) or to alternate between circles 4 and 10. The number of errors made by participants was scored. We also considered three possible types of errors. The first type (I) was the perseverations at the stimulus-response or the set level. The second (II) was the application of the other rules that were previously relevant. The third (III) was bizarre responses and guesses, that is, responses that could not be included in first on second type since no apparent rationale could be discovered.

The Hayling task (Burgess and Shallice, 1996b)

The Hayling task assesses the capacity to suppress (inhibit) a habitual response and was initially divided into two sections to examine both initiation (automatic) and inhibition (non-automatic) processes. This task consists of sentences in which the final words are omitted, but there is a particularly high probability of one specific response. The task consisted of two sections (A and B), each containing 15 sentences. In section A (initiation), sentences were read aloud to the subject who had to complete the sentence with the missing word. In section B (response suppression), sentences were read aloud to the subject who this time had to complete the sentence not with the expected word but with a word unrelated to the sentence. These responses were scored 3 if the word made sense of the sentence, 1 if, although not making sense, it was semantically connected to the sentence and 0 if it made no sense at all. In both sections, subjects were asked to reply as quickly as possible and performance was measured by the time taken to respond (latency).

The alpha-span task (Belleville et al., 1998)

The alpha-span investigated the ability to manipulate information stored in working memory by comparing the recall of information in serial order (implicating mainly a storage component) and in alphabetical order (implicating storage and manipulation of information). Firstly, a classical word-span task was administrated to assess the span level of each subject. Then, the subject was asked to repeat word sequences in two different conditions: direct recall and alphabetical recall. In both conditions, the number of words to be recalled corresponded to the subject's span minus one item. In the direct condition, the subject performed an immediate serial recall of ten sequences of words. In the alphabetical condition, the subject was asked to recall ten sequences of words in their alphabetical order. Comparing the performance on alphabetical recall to that in serial recall assessed the subject’s performance.

Statistical analyses

All statistical analyses were carried out with the Statistical Package for the Social Sciences (SPSS) version 10.0 for Windows (Release 10.0.7 [1. June 2000] Chicago: SPSS Inc.). For analyzing the profile of the IGT performance we conducted ANOVAs with repeated measurements with 'BLOCK' as within-subject factors. Post-hoc analyses were t-test with Bonferoni correction. For calculating the relationship between different executive functions scores and IGT performance we used multiple stepwise regression analyses with different IGT blocks as dependent variable and the executive as well as clinical characteristics as independent variables.

Results

Table 1. Demographic and clinical variables of alcoholics (ALC) and controls (CONT)*

	ALC (n=30)	CONT (n=30)
Age	45.8 (9.5)	44.1 (8.9)
Gender (F/M)	10/20	11/19
Years of heavy drinking	14.05 (8.7)	-
Education (total years)	10.7 (2.0)	10.8 (2.5)
TQADC (in gram)[1]	352.5 (240.5)	16.2 (12.8)
Number of prior detoxification treatments	4.5 (1.7)	-
Number of abstinence days	19.3 (2.5)	2.1 (1.4)
Cumulated diazepam doses during detoxification (in mg)	737 (211)	-
MADRS score	11.9 (9.8)	0.6 (0.7)
STAI – X1 score	43.4 (13.1)	30.8 (5.9)
STAI – X2 score	50.2 (10.4)	33.6 (8.1)

[*] Data are given as mean ± SD ; [1] Standard drink is one which contains roughly 10 grams of alcohol

ALC and CONT groups were similar in term of age (t_{58}=0.58, p>.05), sex (Ch^2=0.73, p>.05) and educational level (t_{58}=-0.06, p>.05). However, daily consumption of alcohol [F_{58}=7.6, p<.001], depression [F_{58}=6.3, p<.001], Spielberger trait anxiety inventory (STAI) [F(1,78)=4.5, p<.001] and Spielberger state anxiety inventory (STSI) [F_{78}=3.8, p<.001] were higher in ALC than in CONT. (See Table 1)

IGT decision making performance

A repeated measures ANOVA was performed, with group as between subjects factor, stage (5 blocks of 20 trials) as a within subjects factor, and the net score [(C+D)-(A+B)] as the dependent measure. This analysis revealed an effect of stage, [F(4,55)=13.7, p<.001], a group effect [F(1,58)=9.99, p=.003] and a group by stage interaction [F(4,55)=3.6, p=.01]. Results of the IGT are presented in the Fig. 1.

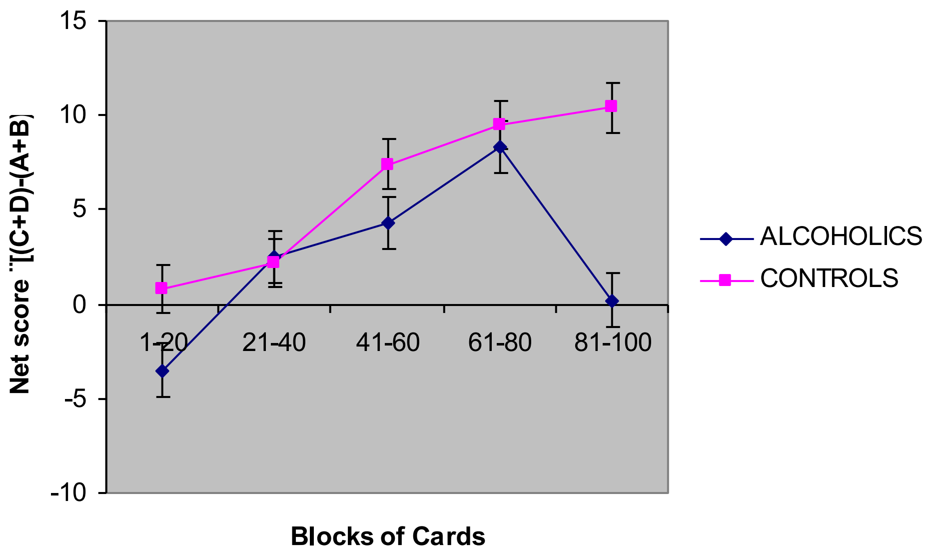

Fig. 1. Means of net score of performance of the IGT in ALC and CONT. Scores on the Gambling Task are the difference between the total number of cards chosen from the advantageous decks (C+D) minus the total number of cards chosen from the disadvantageous decks (A+B). Data are presented as means $\pm$ sem.

The table 2 indicates that a higher proportion of ALC than CONT was impaired in the IGT.

Table 2. Proportion of CONT and ALC who were non-impaired or impaired on the IGT. Impaired subjects are those with net score of <10. Non-impaired subjects are those with net score of >10.

	Non-Impaired	**Impaired**
ALC	53% (n=16)	47% (n=14)
CONT	87% (n=26)	13% (n=4)

Chi-Square=7.1, p<0.01

Table 3. Cognitive, demographical and Alcohol-related measures of ALC who were impaired or not on the IGT. Impaired ALC are those with net score of <10. Non-impaired subjects are those with net score of >10.

	Non-impaired (n=16)	Impaired (n=14)
TQADC (in gram)*	279 (190)	436 (270)
Number of prior detoxification treatments *	2.2 (1.8)	5.6 (2.9)
Years of heavy drinking *	12.3 (9.1)	15.6 (8.4)
MADRS score	9.5 (7.4)	14.5 (11.6)
STAI – X1 score	42.9 (13.9)	44 (12.5)
STAI – X2 score	50.6 (10.5)	49.8 (10.5)
Education (total years)	11.3 (2.2)	10.1 (1.5)
Alpha Span task (working memory)	57.4 (23.9)	67.5 (19.9)
Hayling task (response inhibition) Penalty score	 9.0 (3.7)	 8.3 (3.8)
Brixton task (rule		

detection) Mean number of correct responses	23.9 (9.4)	28.1 (8.4)

* $p<.05$

The two-way ANOVA 2 groups (ALC, CONT) x 2 net score parts [part 1 (trials 1-40), part 2 (trial 61-100)] revealed a main effect of part [$F(1,58)=40.4$, $p<.001$], a main effect of group [$F(1,58)=11.5$, $p=.001$] and a significant interaction part x group [$F(1,58)=3.4$, $p<.05$], with ALC performing more disadvantageously than CONT on the part 2 ($p<.05$). Besides, the correlation between the part 1 and 2 of the IGT did not reach the significant level [$r(30)=.18$, $p=.34$]. (see Figure 2)

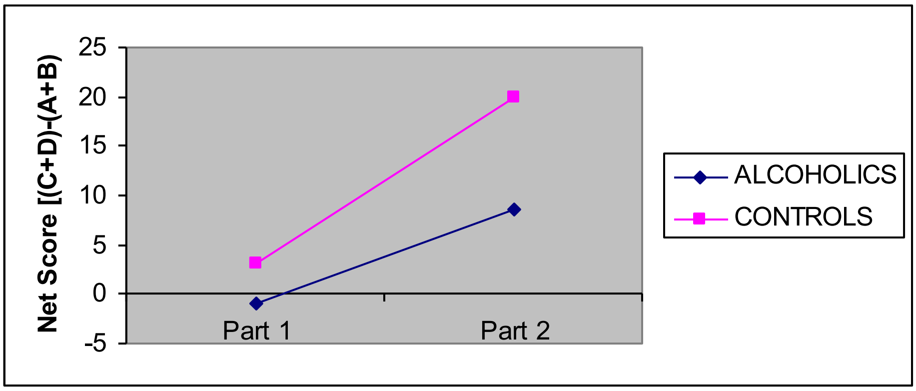

Fig 2. Means of net score of performance of the IGT in part 1 (first 40 trials) and in part 2 (last 40 trials) in ALC and CONT. Scores on the Gambling Task are the difference between the total number of cards chosen from the advantageous decks (C+D) minus the total number of cards chosen from the disadvantageous decks (A+B). Data are presented as means $\pm$ sem.

Other cognitive performances:

Alpha span task performance

The two-way ANOVA for repeated measures with group as between factor and the type of recall (serial, alphabetical) revealed a main effect of type of recall [F(1,58)=87.6, p<.001], of group [F(1,58)=39.9, p<.001] and a significant interaction of the two factors [F(1,58)=47.1, p<.001], with ALC making more errors to recall words in alphabetical than in serial order than CONT [t(1,58)=-7.1, p<.001] (see Table 3).

Table 3. Cognitive performances in alcoholics (ALC) and controls (CONT)

	ALC (n=30)	CONT (n=30)
Alpha Span task (working memory)		
Word span Size	4.7 (0.7)	4.9 (0.6)
Serial recall score	9.3 (0.8)	9.5 (0.6)
Alphabetic recall score*	5.8 (2.1)	8.9 (1.1)
Manipulation score*	62.8 (22.1)	94.4 (11.2)
Hayling task (response inhibition)		
Mean RT initiation (in sec.)	9.3 (2.6)	8.8 (1.5)
Mean RT inhibition (in sec.)*	83.4 (45.9)	49.8 (11.8)
Total Penalty score*	8.7 (3.7)	1.3 (0.9)
Brixton task (rule detection)		
Mean number of correct responses*	26.2 (9.0)	37.02 (4.4)
Errors type 1 (in %)		
Errors type 2 (in %)*	21.6 (12.9)	25.4 (7.4)
Errors type 3 (in %)*	41.6 (14.5)	72.3 (7.0)

	31.6 (15.6)	2.3 (3.0)

*p<.001, ** p<.01

Hayling task

In a two-way ANOVA for repeated measures with group as between factor and the type of condition (initiation, inhibition) for the mean reaction time, we found a main effect of type of condition [F(1,58)=169.4, p<.001], of group [F(1,58)=16.1, p<.001] and a group by type of condition interaction [F(1,58)=13.9, p<.001]. ALC were significantly slower than CONT to give answer when the task requiring to complete the sentences with a semantically unrelated word (section B) but not on section A (p<.001) where the semantically related word is needed (section A).

Regarding the responses' quality, ALC made more penalty errors than CONT [F(1,58)=10.6, p<.001].

Brixton task performance

On this task, ALC had fewer correct response than CONT [F(1,42.2)=-5.9, p<.001]. The analyse of their responses revealed that they made fewer errors of type 2 [F(1,41.89)=-8.8, p<.001] but more errors of type 3 [F(1,31.5)=10.8, p<.001].

Specific executive control task performance as predictors of IGT performance

When considering participants' performance on the IGT, regression analyses were performed with the net score calculated on 1-100 trials, the net score of the first part (1-40 trials) and the second part (61-100 trials) as dependent variable and the number of correct responses in the Brixton test, the penalty score of the Hayling test and the manipulation score of the alpha-span task. Using a stepwise linear regression analyse, we found that the inhibition score of the Hayling test predicted 6.7 % of the first and 19.5 % of the second part of IGT's total net score's variance [$F(1,59)=5.3$, $p<.05$, $F(1,59)=15.3$, $p<.0001$, respectively]. All other predictors (rule detection and manipulation scores and group) were excluded because they did not explain more IGT's variance. When considering only ALC who had a net score lower than 10 (cut-off score corresponding to the best performance obtained by patients with ventro-medial prefrontal cortex damage; Bechara et al., 2001), the inhibition score of the Hayling test predicted 82% of the IGT's total net score [$F(1,13)=56.3$, $p<.001$]. When net scores of IGT's part 1 and 2 were analyzed separately, we found that the inhibition score of the Hayling test predicts merely the part 2 IGT's performance [$r=.57$, $F(1,13)=5.6$, $p<.05$].

Discussion

In this study, we aimed to examine in sober and recently detoxified patients with alcoholism (ALC) the relative contribution of several executive functions to decision-making evaluated by the Iowa Gambling Task (IGT). Compared to their matched healthy controls (CONT), ALC showed below normal level of performance in the IGT, particularly in the second part. In addition, they were impaired on cognitive tasks assessing dominant response inhibition, rule detection and coordination of dual-task. Regression analyses revealed that response inhibition best predicts ALC's impaired performance on the second part of the IGT.

In the IGT, ALC performed lower than CONT in that they picked more cards on the decks A and B, which provides immediate higher amount of money but still more monetary losses in the long run. These results are comparable to those reported by Goudriaan et al. (2005) in detoxified alcoholics similar in age and gender to our sample but abstinent from alcohol for a longer period of time (between 3 and 12 months). The most striking difference between these two studies is that we found in ALC a decreasing of performance during the last 20 trials; they picked more cards from the disadvantageous decks. This difference may be explained as the consequence of cognitive recovery throughout a period of abstinence from alcohol. Indeed, it may be that those patients remaining abstinent for several months were after 3 weeks of sobriety cognitively less impaired than those who relapsed immediately after a detoxification program. Besides, the proportion of 'early alcohol relapsers' is not negligible: they represent around 50% of alcoholics who realized an alcohol detoxification program with success (Tonigan, 2003). Also, it has been shown that executive functioning may mediate the relationship between just detoxified alcoholics and alcohol consumption (Noël et al., 2002). Thus, it is plausible that alcoholics recruited in Goudriaan's study were less cognitively impaired than our patients since they achieved remaining abstinent longer.

Why did ALC return to a disadvantageous decision-making strategy during the second part of the task? According to recent theoretical suggestion (Bechara et al., 2004; Brand et al., 2006), the beginning and the end of the IGT may tap into distinct type of decision-making. During approximately the first 40 trials, the decision is likely to be made without knowledge of the possible outcomes or the probabilities for reward and punishment (i.e., decision under ambiguity). In contrast, during the last 40 trials, although the possible outcomes are also uncertain, they are described by some probability of each one occurring (i.e., decision under risk). Of course, the point in time when decision shift from ambiguity to risk is probably individually different. It is possible that individuals with alcoholism have not acquired explicit knowledge about the task until the 20 last trials but we do not provide direct evidence supporting this idea. However, our results indicate that ALC are impaired in the second part of the task, which suggests impaired decision-making under risk. Interestingly, our results in the IGT resemble to performance obtained by Casino gamblers (Goudriaan et al., 2005). Common personality traits between ALC and Casino gamblers could explain this behaviour similarity in the IGT: they both seek out heighten arousal, thus being boredom prone and high sensation seekers (e.g., Cocco et al., 1995). Another but compatible explanation could be that the resiliency to stay with a deck after these participants groups experience a loss could indicate they hope to regain money lost before on the same deck (result of a phenomenon in gambling known as ‘chasing losses’). Further studies should be conducted to investigate both personality traits and inefficient thoughts involved in the IGT’s realization.

Also consistent with previous results (Bechara et al., 2001; Bechara et al., 2002), we found a subgroup of ALC (53%) with normal performance in the IGT, in that they obtained a net score >10, which means that they performed better than all the patients with ventromedial lesions (VM) (Bechara et al., 2001). In contrast, the 47% of ALC remaining performed the IGT within the range of VM, which means that a subgroup of ALC exhibit severe decision-making impairment. This finding suggests a non-causal relationship between decision-making as assessed by the IGT and alcoholism: poor decision-making does not necessary lead to alcoholism and alcoholism is not always associated with impaired decision-making in the IGT.

In order to examine the relationship between executive functioning and making-decision, we administrated cognitive tasks assessing the inhibition of the dominant response, the detection of the abstract rules and the manipulation of information stored in working memory.

On the response inhibition task (the Hayling test, Shallice and Burgess, 1996), ALC were slower on the inhibition section, but not on the section requiring to produce an automatic response. They also made more inhibition errors than the CONT. In accordance with other studies (e.g., Noël et al. 2001, 2002), the observed dissociation between initiation and inhibition sections tackles directly the automatic/controlled distinction proposed by the model of Norman and Shallice (1980): deficits in ALC are observed in the controlled process allowing the inhibition of a dominant response but not the production of an automatic response. This finding is compatible with other studies' results showing that subject with alcoholism perform under the normal limit on a variety of response inhibition tasks including the Wisconsin Card Sorting task (e.g., Ratti et al., 2002), the go-no/go paradigm (e.g., Kamarajan et al., 2005; Noël et al., 2005), the alternate-response task (e.g., Hildebrandt et al., 2004), the trial-making test (e.g., Noël et al., 2001) and the Stroop test (e.g., Noël et al., 2001).

The results of the Alpha-span task (Belleville et al., 1998) showed that, in ALC, the normal storage component of working memory (measured by the span size and the score of serial condition) remains healthy but the ability to manipulate the information stored (measured by the alphabetic condition) is impaired. The observed dissociation between normal non-executive and abnormal executive components of working memory is compatible with studies showing that ALC perform below the normal level on the Brown-Peterson task (e.g., Kessler et al., 1987), on a complex span task (Rapeli et al., 1997) and on the delayed alternation task (Ambrose et al., 2001).

The results in the rule detection test (Brixton test, Burgess and Shallice, 1996) revealed that ALC responded similarly to the frontal patients: they made more errors than CONT, particularly more illogical responses (guesses). In contrast, the two groups wade a similar number of perseverative errors, which suggest that ALC's performance was not affected in this task by an inability to inhibit the automatically trigger over-learned stimuli. Rather, following the example of patients with brain lesions affected the left convexity of frontal cortex (Reverberi et al., 2005), ALC performed like they were less efficient to induct reasoning (for similar results, see Noël et al., 2001).

The exploration of the relative influence of executive functioning on decision making emphasized the significant contribution of response inhibition to IGT's performance in ALC during the last 40 trials of the task (decision under risk). According to Bechara (2004), contrary to decision under ambiguity requiring mainly implicit processes (e.g., somatic markers), decision under risk could beside involve executive functions. Our results suggest that ALC exhibit a decision-making under risk deficit partially associated with response inhibition deficit. They are in line with study showing that the reaction time on the Delay Discounting Procedure was correlated to the net score of the last 50 trials of the IGT (Monterosso et al., 2001). Also, in a recent study, Brand et al. (in press) calculated correlations between executive functions and IGT performance separately for five blocks of IGT trials (each having 20 trials). They found that in a large sample of 97 healthy subjects, only the last blocks of trials were correlated with WCST measures whereas the first IGT block was not. In addition, the involvement of executive functions has been attested by the means of another explicit gambling task, the Game of Dice Task (GDT, see the detailed task description in Brand et al., 2005). The GDT requires individuals to decide between different alternatives that are explicitly related to a specific amount of gain/loss and have obvious winning probabilities. In a series of studies with different groups of patients – that is in subjects with Korsakoff's syndrome (Brand al., 2005), patients with Parkinson's disease (PD) (Brand et al., 2004) and pathological gamblers (Brand et al., 2005) – severe deficits in GDT performance were correlated with performance in categorization and mental flexibility, measured with the modified WCST.

As an explanation of the observed associated between response inhibition and decision-making under risk on the IGT, it might be that the first choice coming up to subjects' mind (or that is loaded into working memory) and possibly considered inappropriate should then be suppressed (or inhibited) at the profit of another option. In the absence of satisfactory efficiency of response inhibition, it is likely that the final choice will be the first one taken into account.

It is likely that the decision-making deficits found in ALC have to be attributed to alcoholism, since levels of comorbid, depression, anxiety, cumulated quantity of diazepam were not associated with performance levels of the IGT.

The present study has some limitations. The first limitation is that we posited that explicit rules of the IGT were not influence participants' decision during the first 40 trials on the basis of previous works (e.g., Bechara et al., 1997) in which participants reported none or not much knowledge about IGT's reward/punishment contingencies. However, we do not know when decision shift from ambiguity to risk in individuals with alcoholis. Beside, Maia and McClelland (2004) objected that the way Bechara and Colleagues investigated what participants really know in the IGT was not a reliable method. By using more sensitive means, they showed that participants have much more knowledge about the game than previously thought, thus making the distinction between decisions under ambiguity and under risk still uncertain. In order to settle the question, it would be fruitful to use in ALC accurate questionnaires to investigate explicit knowledge throughout the realization of the IGT.

The second limitation is that we do not know whether cognitive deficits in alcoholic subjects recover after a longer period of abstinence and if poor decision made under risk in the IGT predict alcohol relapse. Further longitudinal studies should be conducted to explore these important questions.

In sum, ALC exhibit severe decision-making impairment as attested by a below normal level of performance in the IGT, particularly during the second part of the task when decision are thought to be made under risk rather than under ambiguity. Besides, low performance in the last 40 trials of the IGT is best predicted by the score of response inhibition, thus suggesting the involvement of response inhibition to make advantageous decisions when explicit information about the risks is available.

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