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Delayed transition from ambiguous to risky decision making in alcohol dependence during Iowa Gambling Task

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ABSTRACT

It has been demonstrated that alcohol-dependent patients exhibit decision-making deficits, particularly, hypersensitivity to reward and executive dysfunction. Yet, how the impaired motivational process and executive dysfunction in the patients affect decisions under ambiguity and risk with different degrees of uncertainty is little known. To investigate the neuropsychological origin of the impaired decision making under uncertainty in alcohol dependence, we administered the Iowa Gambling Task (IGT), Game of Dice Task (GDT) and Wisconsin Card Sorting Test (WCST) to 23 alcohol-dependent patients and 21 healthy subjects, and calculated the correlations between the task performances. We found that the patients showed poor performance in all three tasks compared with the healthy subjects. Moreover, correlations between performances on the GDT and the later trials of the IGT were delayed in alcohol-dependent patients when compared with healthy subjects. There is also a significant correlation between performances of earlier trials of the IGT and the WCST in the patients. These findings suggest that executive dysfunction in alcohol-dependent patients hampers appropriate estimation of probability distributions of possible alternatives, leading to a delayed transition from ambiguous to risky conditions in the Iowa Gambling Task.

1. Introduction

Human decision making includes the prediction of possible outcomes, the evaluation of alternatives, the selection of action and the learning from behavioural feedback (Ernst and Paulus, 2005). According to the degree of information possessed, decision-making situations can be classified into decisions made under conditions of ambiguity and risk (Ellsberg, 1961; Goel et al., 2007). In ambiguous conditions, the decision should be made between different options without explicit knowledge of possible results and probability of reward and punishment. By contrast, in risky situations, people should make choices between options resulting in reward or punishment. As stated by behavioural economists, there is a general tendency in people for an aversion to ambiguity, and recent neuroimaging studies have identified the neural substrates of decisions under ambiguity and risk (Volz et al., 2005; Krain et al., 2006; Yoshida and Ishii, 2006). Accordingly, the lateral prefrontal cortex is implicated in inhibition of the impulsive aversion to ambiguity and contextual analysis to resolve the uncertainty, whereas the dorsal striatum and the posterior parietal cortex play a role in the evaluation of prospective risky outcomes. In addition, the amygdala, the striatum and the orbitofrontal cortex (OFC) are engaged in encoding the level of uncertainty (Hsu et al., 2005; Huettel et al., 2006).

It has been shown that addiction patients exhibit persistent behavioural pathologies even after a long period of abstinence (Kalivas and Volkow, 2005). In general, executive dysfunction, visuospatial disorganisation and ataxia were frequently observed in chronic dependence patients (Scheurich, 2005; Sullivan and Pfefferbaum, 2005). Particularly, there is an accumulating body of evidence showing impaired decision making in patients with alcohol dependence. One of the useful tasks to investigate the decision-making process under ambiguity and risk is the Iowa Gambling Task (IGT). The IGT is a psychological task thought to simulate real-life decision making, particularly a gambling situation. Healthy participants initially explore the outcome of each option under ambiguity and eventually choose stable reward where the risks and benefits are more explicit. This was originally developed to assess the decision-making ability of patients with lesions of the OFC, but has been intensively applied to evaluate the ability to make decisions which take into consideration the amount of both immediate reward and future punishment in various neuropsychiatric patients (Dunn et al., 2006; Verdejo-Garcia et al., 2007a; Hanson et al., 2008; Passetti et al., 2008). Especially, in the IGT, alcohol-dependent patients manifest inferior performances by

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selecting more cards from disadvantageous decks than do healthy subjects (Mazas et al., 2000; Kim et al., 2003; Fein et al., 2004; Dom et al., 2006b; Loeber et al., 2009; Miranda et al., 2009; Salgado et al., 2009). Early-onset alcohol-dependent patients show abnormal preference for immediate reward in the delay-discounting task, which assesses intertemporal choice and impulse control in decision-making situations (Dom et al., 2006a; Bickel et al., 2007). In addition, deficits in emotional processing and theory of mind were found in abstinent alcohol-dependent patients (Clark et al., 2007; Uekermann et al., 2007). As an underlying psychological mechanism of the extensive decision-making deficits in alcohol dependence, excessive attribution of motivational salience to reward and executive dysfunction have been suggested to explain the anomalous decision-making capacity in alcohol dependence (Robinson and Berridge, 2003; Fein and Chang, 2008).

The IGT has, however, too low a specificity to dissociate subcomponents of the decision-making process, in spite of its relatively high sensitivity. For instance, compromised working memory is sufficient to delineate anomalous decision making in certain psychiatric patients, but not vice versa, that is, impaired decision making may occur for many reasons other than working memory (Bechara et al., 1998; Bechara and Martin, 2004). To disentangle the underlying elements of the complex decision-making process in the IGT, several decision-making tasks including variants of the IGT have been devised and their relations to the IGT have been investigated (Kim et al., 2003; Fellows and Farah, 2005; Sinz et al., 2008).

In this study, we attempt to focus more on the behaviour of alcoholic patients during the IGT under ambiguity and risk to get an insight into their inferior performance of the IGT. With respect to the issue of ambiguity and risk, subjects undergo different levels of uncertainty during the performance of the IGT from ambiguity to risk, because they should characterise stochastic properties of individual decks using only implicit information from previous trials. Interestingly, several variants of the IGT are developed to be suitable for investigating their abnormal behaviour of IGT under ambiguity and risk. Among them, the GDT allows us to simulate decisions under risk with explicit and stable rules for gains and losses (Brand et al., 2004). Thus, participants are able to optimise their performance by deliberately pondering cost–benefit analysis and calculating the expected utility. The progressive shift from ambiguous to risky situations in the IGT can be revealed by calculating correlations between performances of the GDT and individual blocks of the IGT (Brand et al., 2007). For alcohol-dependent patients, how the impaired motivational process and executive dysfunction observed in the patients affect their decisions under ambiguity and risk with different degrees of uncertainty is little known.

The aim of the current study was to investigate the neuropsychological origin of the impaired decision making in alcohol dependence. We recruited 23 patients with alcohol dependence and 21 healthy subjects to perform the IGT, GDT and Wisconsin Card Sorting Test (WCST), and calculated the correlations between performances in the GDT, WCST and individual blocks of the IGT in each group. These correlations may provide insights into the timing of the transition from ambiguity to risk and the role of executive functions during performance of the decision-making tasks as well (Brand et al., 2007; Noel et al., 2007). Based on previous studies, our hypothesis was that alcohol-dependent patients would display an anomalous decision-making profile on the IGT, GDT and WCST. In addition, we posited that there is a delayed shift from ambiguity to risk during performance of the IGT, which might be arising from disturbance in the resolution of uncertainty (Huettel et al., 2005; Yoshida and Ishii, 2006; Yang and Shadlen, 2007).

2. Methods

2.1. Subjects

Twenty-three patients with alcohol dependence and 21 healthy subjects participated in this study. All subjects were male to exclude gender effects. Alcohol-dependent patients were recruited from the Drug Abuse Center, the Department of Psychiatry of Bugok National Hospital and their consensus diagnoses were established according to Diagnostic and Statistical Manual of Mental Disorders fourth edition (DSM-IV) criteria by two psychiatrists using a semi-structured interview. They were in-patients with a stabilised life. Exclusion criteria of alcohol-dependent patients for this study included past neurological illness, traumatic brain injury, mental retardation, other substance abuse except caffeine and nicotine and lifetime axis I psychiatric disorders other than alcohol dependence. To ensure that subjects were alcohol-free at the time of testing, all alcohol-dependent patients were tested after at least 2 weeks of abstinence. The severity of alcohol dependence and alcohol craving was measured using the Korean version of the Michigan Alcohol Screening Test (MAST) (Selzer, 1971; Chang and Cheon, 1985). All of the patients in this study were selected as moderate to severe, based on MAST scores (mean MAST score with standard deviation: 25.78 ± 10.16). The Korean Wechsler Adult Intelligence Scale-Revised was used as a comprehensive test of intelligence quotient (IQ) for both groups (Yum et al., 1992).

Healthy subjects were recruited as volunteers from the neighbouring towns of Bugok National Hospital. They were selected based on age, sex, education level and IQ similar to those of psychiatric patients. Healthy subjects also had psychiatric interviews to rule out histories of a neurological disorder, such as seizure, stroke, head injury and previous history of substance dependence except caffeine and nicotine or lifetime axis I psychiatric disorders. The Institutional Review Boards (IRBs) of Bugok National Hospital approved all experimental procedures for this study. All subjects from two groups presented written informed consent approved by the IRB, after receiving detailed explanation of the research and experimental procedures.

2.2. Procedures

All participants underwent computerised versions of the IGT, GDT and WCST with a randomised order of task administration.

2.2.1. IGT

The subjects were instructed that the goal of this game is to win as much money as possible within 100 trials (Bechara et al., 2000). However, the subject did not know explicitly when the game ends. The subject was free to switch from one deck to another at any time and as often as he wished. In the disadvantageous decks A and B, selecting a card is followed by a $100 reward, and, in the advantageous decks C and D, a $50 reward. However, every 10 cards from the disadvantageous (advantageous) decks cost $1250 ($250) in an unpredictable manner. A net score is then obtained by subtracting the total number of disadvantageous decks from that of the advantageous decks ((C + D) − (A + B)) for the overall 100 cards and each block of 20 cards.

2.2.2. Game of Dice Task

In this task, the subjects are instructed to gain as much fictitious money as possible within 18 dice throws. They can choose between different single numbers or a combination of two, three or four numbers. The available options consist of $1000 gain/loss for the choice of a single number (a winning probability of 1:6), $500 gain/loss for two numbers (2:6), $200 gain/loss for three numbers (3:6) and $100 gain/loss for four numbers (4:6). Thus, the choices of one or two numbers with a winning probability of less than 50% can be considered as risky decisions, whereas the choices of three or four numbers with a winning probability of 50% or higher are relatively safe decisions.

2.2.3. Wisconsin Card Sorting Test

The computerised version of the WCST, a commonly used measure of working memory, categorisation, concept formation, task monitoring and cognitive flexibility, was administrated (Heaton, 1993). The subjects sort response cards until they have matched six categories or sorted all 128 cards. Cards are matched according to different dimensions such as colour, form and number. After 10 consecutive correct card sorts, a new sorting principle is instituted without warning. Measures of performance include the number of categories completed, total errors and perseverative errors.

2.3. Statistical analysis

The independent-samples' t-test and 2(group) × 5(blocks of 20 cards) repeated-measure analysis of covariance (ANCOVA) were used to compare the demographic characteristics and the performances of neuropsychological tests between the two groups. We controlled for demographic variables with ANCOVA, if they differed between groups and were correlated with dependent variables. We used Pearson correlations after testing the assumption of normal distribution with the Kolmogorov–Smirnov test. In the case of rejecting the null hypothesis, non-parametric Spearman correlations were calculated. An alpha level of 0.05 was used to judge whether findings were statistically significant. Bonferroni correction was also used to remove type I error, which is indicated as ***.

3. Results

Demographic characteristics for the patients and healthy subjects are summarised in Table 1. Groups did not differ significantly in age, gender or IQ but differed in education level. Furthermore, the

Table 1
Demographic and clinical information about the alcohol-dependent patients and healthy subjects.

	Alcohol-dependent patients, mean (S.D.)	Healthy subjects mean, (S.D.)	*t*	*df*	*P*
Total *N*	23	21			
Age (years)	32.65 (5.10)	30.52 (2.98)	-1.67	42	0.103
Education (years)	11.26 (2.77)	15.14 (1.20)	6.13	30.51	<0.001*
IQ	98.43 (7.77)	102.86 (10.34)	1.61	42	0.114
Duration of illness (years)	4.91 (3.64)				
MAST	25.78 (10.16)				

MAST, Michigan Alcohol Screening Test.
* $p<0.01$.

education level was correlated with the net score of the IGT ($r=0.467$ and $P=0.001$) as well as the number of completed categories ($r=0.546$ and $P<0.001$), total errors ($r=0.549$, $P<0.001$ and corrected ***) and the perseverative errors ($r=0.500$, $P=0.001$ and corrected ***) of the WCST.

Differences in the performances on the IGT, GDT and WCST were evaluated using ANCOVA, with the education level as a covariate of no interest (Table 2). In the IGT, the alcohol-dependent patients made decisions in a disadvantageous way, regardless of the frequency of punishments, which was revealed by a detailed comparison of the number of chosen cards from each deck. In the GDT, the patient group selected more cards from risky decks compared with healthy subjects. In the WCST, groups differed significantly in the number of completed categories, total errors and perseverative errors. Taken together, these results indicate increased risk-taking behaviour and executive dysfunction in the alcohol-dependent patients.

To specifically assess the chronological patterns of selections in the two groups during the IGT, we conducted 2(group)×5(blocks of 20 cards) repeated-measure ANCOVA (Fig. 1) and found the main effect of group (i.e., the between-subjects factor) ($F(1,41)=10.906$ and $P=0.002$) and the group×block interaction effect ($F(1,41)=3.653$ and $P=0.013$). *Post hoc* independent-samples *t*-tests revealed significant group differences for the third ($F(1,41)=10.318$ and $P=0.003$), fourth ($F(1,41)=10.186$ and $P=0.003$) and fifth ($F(1,41)=7.315$, $P=0.010$) blocks in the IGT. These results demonstrate that the alcohol-dependent patients exhibited compromised performance in the later trials of the IGT.

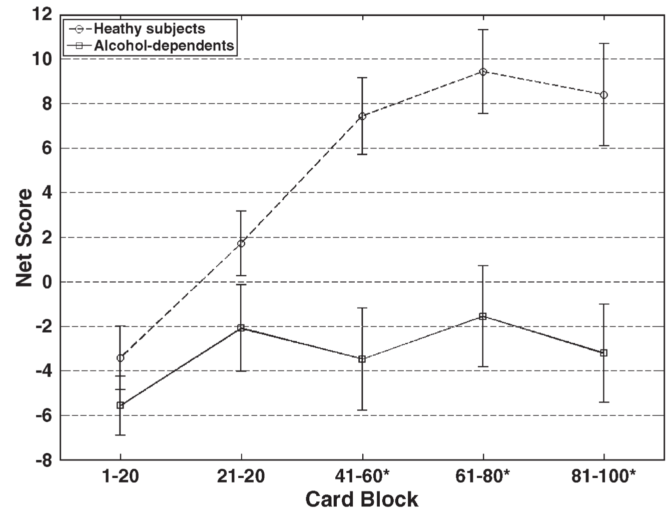

Fig. 1. Temporal patterns of the neuropsychological performance (mean net score) on the five blocks of the IGT. Significant differences were found between two groups in the 3rd block ($F(1,41)=10.318$, $p=0.003$), the 4th block ($F(1,41)=10.186$, $p=0.003$), and the 5th block ($F(1,41)=7.315$, $p=0.010$).

The correlations between performances on blocks of IGT and other neuropsychological tests are summarised in Table 3. In the case of the alcohol-dependent patients, the MAST score was included in the correlation analysis. In the healthy subjects, the number of risky choices in the GDT was correlated significantly with the net score of the third block ($r=0.478$ and $P=0.028$), the fourth block (= 0.502 and $P=0.020$), the fifth block ($r=0.561$ and $P=0.008$) and the total net score ($r=0.620$ and $P=0.003$) on the IGT (Fig. 2). The alcohol-dependent patients showed the correlations between the net score of the second block of the IGT and the number of completed categories

Table 2
Neuropsychological performances on the IGT, GDT, and WCST with the number of selections.

	Alcohol-dependent mean, (S.D.)	Healthy subjects mean, (S.D.)	*F*	*df*	*P*
Iowa Gambling Task					
Net score	-12.78 (27.87)	23.52 (29.17)	7.37	1	0.009**
Deck A	26.13 (12.97)	18.05 (8.29)	4.59	1	0.038*
Deck B	31.83 (15.96)	20.19 (7.52)	4.54	1	0.039*
Deck C	22.00 (8.74)	29.67 (12.13)	3.84	1	0.057
Deck D	20.04 (12.63)	32.10 (12.93)	5.47	1	0.024*
Game of Dice Task					
Risky choice	10.61 (6.70)	5.33 (3.80)	7.71	1	0.008**
One number choice	6.22 (6.76)	1.10 (1.70)	7.15	1	0.011*
Two numbers choice	4.39 (4.46)	4.24 (3.32)	0.21	1	0.652
Three numbers choice	2.74 (2.93)	7.90 (3.63)	13.38	1	0.001**
Four numbers choice	4.65 (5.46)	4.76 (4.15)	0.45	1	0.508
Wisconsin Card Sorting Test					
Categories completed	2.61 (2.33)	5.76 (0.89)	13.27	1	0.001**
Total errors	55.13 (25.91)	16.76 (16.71)	16.82	1	<0.001**
Perseverative errors	28.96 (16.60)	11.19 (11.10)	8.64	1	0.005**

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

Table 3
The correlations between performances on individual blocks of IGT and other neuropsychological tests.

	IGT-1	IGT-2	IGT-3	IGT-4	IGT-5	IGT-T	MAST
Healthy subjects							
GDT-R	-0.267	-0.354	-0.478*	-0.502*	-0.561**	-0.620**	
WCST-C	0.261	0.327	-0.242	0.260	0.341	0.203	
WCST-TE	0.011	0.101	0.296	-0.394	-0.283	-0.115	
WCST-PE	-0.039	-0.027	0.319	-0.312	-0.186	-0.098	
Alcohol-dependent patients							
GDT-R	0.283	0.082	0.023	-0.347	-0.465*	-0.133	-0.039
WCST-C	0.321	0.525*	0.411	0.043	0.321	0.416*	0.106
WCST-TE	-0.299	-0.475*	-0.394	-0.076	-0.31	-0.379	-0.236
WCST-PE	-0.244	-0.481*	-0.365	0.170	-0.164	-0.263	-0.244
MAST	-0.15	-0.152	-0.064	-0.112	0.102	-0.136	

IGT-1,-2,-3,-4,-5,-T, net scores of 1st block, 2nd block, 3rd block, 4th block, 5th block, total score in IGT; GDT-R, number of risky choices in GDT; WCST-C, -TE, and -PE, number of categories completed, total errors, and perseverative errors of WCST.
* $p<0.05$.
** $p<0.01$.

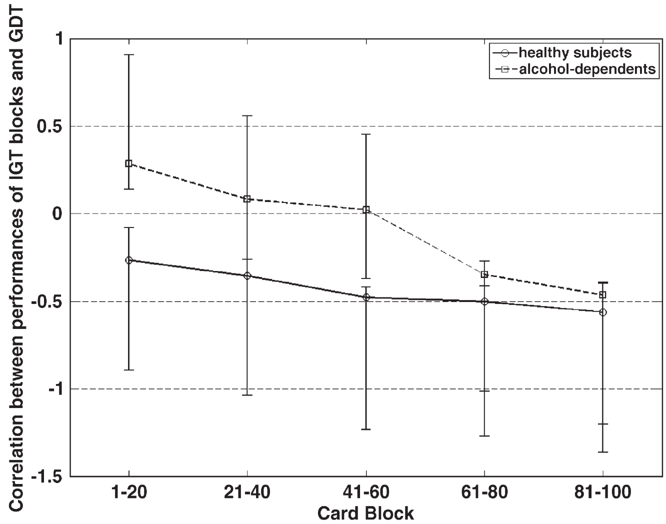

Fig. 2. Temporal patterns of the correlation between performances of individual IGT blocks and GDT within each group. Significant correlations were found in the 3rd block (r = -0.478, P = 0.028), the 4th block (r = -0.502, P = 0.020), the 5th block (r = -0.561, P = 0.008) for healthy subjects as well as in the the 5th block (r = -0.465, P = 0.025) for alcohol-dependents. The error bars represent 95% confidence interval of the correlations for each group.

(r = 0.525 and P = 0.010), that of total errors (r = 0.475 and P = 0.022) and that of perseverative errors (r = 0.481 and P = 0.020) in the WCST reached statistical significance. In addition, there was significant correlation between the number of risky choices in the GDT and the net score of the fifth block (r = 0.465 and P = 0.025) and between the number of completed categories in the WCST and the total net score of the IGT (r = 0.416 and P = 0.048) in the IGT (Fig. 2). These results indicate that the later parts of the IGT correspond to risky situations in both healthy subjects and alcohol-dependent patients. Namely, both groups came to have more accurate information about task structure of the IGT, progressively. However, the alcohol-dependent patients exhibited the transition from ambiguous to risky situations in the fifth block of the IGT, which was delayed compared with the transition in the third block of the IGT in healthy subjects. The temporal pattern of the degree to which subjects with better GDT performance show better performance of the IGT blocks in alcohol-dependent patients was set back by about two blocks, compared with healthy subjects (Fig. 3). Moreover, performances on the WCST were correlated significantly with that on the second block of the IGT in alcohol-dependent patients, indicating the involvement of executive dysfunction in the performance of early trials of the IGT.

Finally, we calculated correlations between the net scores of individual blocks on the IGT to confirm the distinction between them in terms of levels of uncertainty. We found the significant correlations between the net scores of the second and third (r = 0.534 and P = 0.013), the second and fourth (r = 0.434 and P = 0.049), the third and fourth (r = 0.638 and P = 0.002), the third and fifth (r = 0.527 and P = 0.014) and the fourth and fifth (r = 0.875, P < 0.001 and corrected ***) blocks of the IGT in healthy subjects. The alcohol-dependent patients exhibit significant correlations between the net scores of the first and second (r = 0.610 and P = 0.002), the second and third (r = 0.684, P < 0.001 and corrected ***) and the fourth

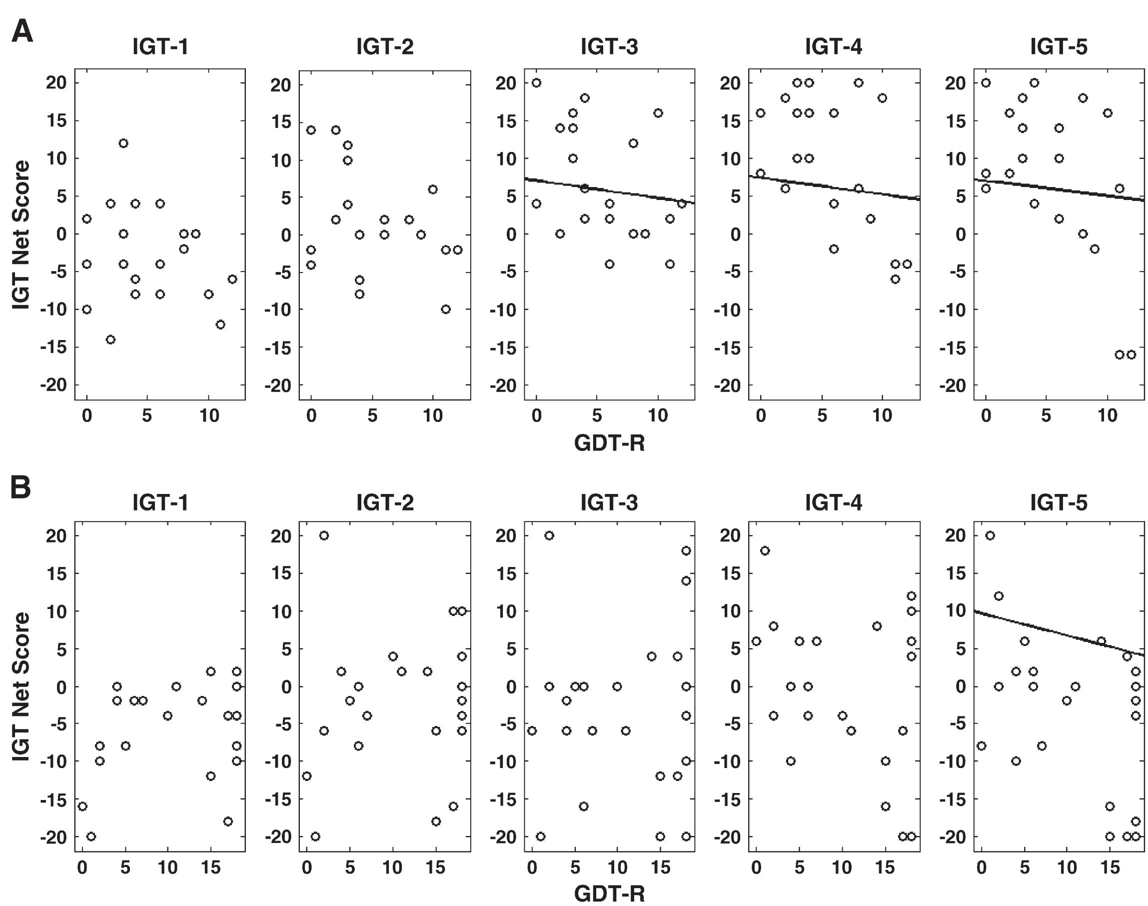

Fig. 3. Scatter plots for the correlation between performances of individual IGT blocks and GDT in (A) healthy subjects and (B) alcohol-dependents. Significant correlations are plotted by solid lines.

Table 4
The correlations between the net scores of individual blocks on IGT.

	IGT-1	IGT-2	IGT-3	IGT-4
Healthy subjects				
IGT-2	0.329			
IGT-3	-0.048	0.534*		
IGT-4	0.010	0.434*	0.638**	
IGT-5	0.038	0.350	0.527*	0.875**
Alcohol-dependent patients				
IGT-2	0.601**			
IGT-3	0.192	0.684**		
IGT-4	0.127	0.246	0.109	
IGT-5	-0.038	0.214	0.120	0.613**

IGT-1,-2,-3,-4,-5,-T, net score of 1st block, 2nd block, 3rd block, 4th block, 5th block, total score in IGT.
* $p<0.05$.
** $p<0.01$.

and fifth ($r=0.613$ and $P=0.002$) blocks of the IGT. These results indicated a delayed dissociation between earlier and later phases of the IGT in alcohol-dependent patients, compared with healthy subjects (Table 4).

4. Discussion

In this study, we assessed the decision-making capacities of alcohol-dependent patients under ambiguous and risky conditions and the relative effect of executive functions on these capacities. Alcohol-dependent patients performed poorly on the IGT and GDT, which represent the decisions under ambiguity and risk, respectively. They exhibited the executive dysfunction on the WCST. In addition, correlation analysis revealed deferred transition from ambiguous to risky situations as well as impaired executive control in early trials of the IGT in alcohol-dependent patients. To the best of our knowledge, the current study is the first to investigate the neuropsychological substrate of deficits in decision making in the IGT in terms of ambiguity and risk in alcohol dependence.

The IGT has been frequently used to examine abnormal decision making in resolving the conflict between immediate large gain and delayed ultimate loss in diverse neuropsychiatric patients (Stefani and Moghaddam, 2006; Yoshida and Ishii, 2006; Sailer et al., 2007). However, owing to its considerable complexity, multiple neuropsychological processes are engaged in the IGT performance, which lead to high variability of performance even in healthy subjects (Maia and McClelland, 2004; Bechara et al., 2005; Dunn et al., 2006). Hence, several modified versions of the IGT and other cognitive tasks have been developed to separate its entangled sub-components (Bechara et al., 2002; Brand et al., 2005; Fellows and Farah, 2005; Kovalchik and Allman, 2006). Among these, it was reported that the IGT is made up of two different situations in sequential order, namely, decisions under ambiguity and risk, whose characterisation was initially proposed in the field of behavioural economics (Brand et al., 2007; Noel et al., 2007). With the GDT as a gambling task under risk, our results showed that the initial portion (i.e., the first and the second blocks) of the IGT corresponds to the ambiguous state and participants learn from the previous outcomes to estimate the probability distributions of each deck as the task proceeds, consistent with the previous finding (Brand et al., 2007). The correlation between the performances of the GDT and the separate blocks of the IGT in healthy subjects notably showed the gradual increased involvement of decisions under risk. The correlation between the net scores of individual blocks in the healthy subjects also supported the distinction between the earlier and later parts of the IGT.

Biased attribution of motivational salience has been possibly suggested as one of the causes for the neuropsychological mechanisms underlying low IGT performance in alcohol dependence. Alcohol-dependent patients exhibit abnormally high sensitivity to reward and the stimuli predicting it, which leads to compulsive and persistent drug taking (Kalivas and Volkow, 2005; Leland and Paulus, 2005; Hyman et al., 2006; Bjork et al., 2008; Fein and Chang, 2008). On the other hand, the compromised executive functions including working memory, response inhibition and cognitive flexibility can also exert a causal effect on aberrant decision-making patterns in alcohol dependence (Noel et al., 2007; Verdejo-Garcia et al., 2007b). We also found in this study that alcohol-dependent patients performed poorly on the GDT and the later trials of the IGT. We speculate that these deficits both in the IGT and GDT (i.e., the enhanced risk-taking behaviour) are possibly associated with disturbed sensitivity to reward and punishment (Gul and Pesendorfer, 2005). Several lines of evidence have shown that in these risky/certainty situations, that is, when rules are more explicit, executive functions are more important than affective factors (Brand et al. 2006, 2008). In the correlation analysis in alcohol-dependent patients, we found the significant association between the performance of the GDT and that of the blocks of the IGT only in the last block. Furthermore, the correlation in the last block resided in a range similar to the correlation in the third block of healthy subjects, although, even in the alcohol-dependent patients, the correlation remarkably showed an increased pattern in an absolute sense. These results suggest that alcohol-dependent patients construct the probability distribution of outcomes on the IGT later by approximately two blocks compared with healthy subjects, in agreement with our hypothesis. In other words, alcohol-dependent patients had problems with using past experiences as a source of limited information or adjusting the learning rate according to the uncertainty level of each IGT block (Rushworth and Behrens, 2008). This two-block delay of ambiguity-to-risk shift was also bolstered by the correlations between the net scores on the block of the IGT in alcohol-dependent patients.

In the performance of the WCST, alcohol-dependent patients completed a smaller number of the categories and made more errors compared with healthy subjects. The neuropsychological mechanisms underlying the performance of the WCST might consist of working memory, categorisation, rule acquisition, concept formation, task monitoring and cognitive flexibility. The result of our study indicates the executive dysfunction in alcohol dependence. In addition, there was significant correlation between the net scores of the second block on the IGT and three measures of the WCST in the alcohol-dependent patients. This implies that the executive dysfunction of the alcohol-dependent patients is implicated in the early part of the IGT, where the induction of rule in the IGT should have taken place. The timing of the involvement of executive function in the IGT was corroborated by the correlation between performances on IGT blocks and GDT in healthy subjects (Dretsch and Tipples, 2007). We speculate that alcohol-dependent patients are not able to encode contextual information based on reward history to appropriately cope with the ambiguous situation of the early part of the IGT.

However, a recent study (Brand et al., 2007) has demonstrated that healthy subjects show significant correlations between only the last blocks of IGT and WCST performance. This is in line with other evidence that showed that the IGT later trials and GDT are more related to 'calculative' decision making and executive functions, but the IGT early trials are more related to 'intuitive' decision making and reversal learning (Brand et al., 2006, 2008). Several studies have suggested that executive functions do not play a major role in the early phases of IGT because it is difficult for subjects to keep track and explicitly remember their gains and losses in the beginning of the task. Furthermore, similar to IGT, WCST is a complex task, where multiple neuropsychological processes and several brain regions are engaged (Nyhus and Barceló, 2009). Hence, any patient dysfunction in any area involved in both WCST and early phases of IGT could contribute to the above-mentioned correlation. Another possible, alternative explanation for the correlation between WCST and IGT second trial could be that patients with a great executive dysfunction (and/or a great sensitivity to reward) may have an anomalous, poor performance, more dependent on intuitive decision making, in the WCST (Brand et al., 2008).

On the other hand, the well-known integrative role of the dorsolateral prefrontal cortex (DLPFC) in executive function and cognitive control suggests its possible involvement in the establishment of probability distributions and ensuing transition from ambiguous to risky conditions (Gunning-Dixon and Raz, 2003; Huettel et al., 2004; Grinband et al., 2006; Kopp et al., 2006; Procyk and Goldman-Rakic, 2006; Seeley et al., 2007; Labudda et al., 2008). It has been reported that the lateral prefrontal cortex plays a role in resolving ambiguity, whereas the posterior parietal cortex is engaged in the assessment of risky situations (Huettel et al., 2006; Krain et al., 2006; Yoshida and Ishii, 2006; Fecteau et al., 2007). Furthermore, alcohol dependence has been shown to have detrimental effects on executive function (George et al., 2004; Goldstein et al., 2004) by influencing the activity of frontal regions, such as the DLPFC and the anterior cingulate cortex (Goldstein et al., 2004; Ridderinkhof et al., 2002; Rushworth and Behrens, 2008).

Some limitations of the study should be considered. First, caution has to be taken because a simple correlation analysis is not able to reveal a causal relation regarding executive dysfunction and delayed shift from ambiguous to risky conditions in alcohol-dependent patients. To get an insight into the causal relationship between executive dysfunction and deficits in decision making, further investigation is required. Second, correlation between the performances of the WCST and that of the IGT was not observed in healthy subjects, in contrast to a prior study (Brand et al., 2007). This lack of the correlation might stem from the low variability in the performance of the WCST in the healthy subjects. A related issue is the small number of subjects in our study, which might contribute to the low variability in our data. Third, we were not able to match the education level between the healthy subjects and the patient group. This difference might affect our analysis as a confounding factor, although we did attempt to minimise the influence of this factor by incorporating the education level as a covariate in the statistical analysis.

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