Neurocognitive Determinants of Novelty and Sensation-Seeking in Individuals with Alcoholism

Xavier Noël1,*, Damien Brevers1, Antoine Bechara2,3, Catherine Hanak4, Charles Kornreich4, Paul Verbanck4 and Olivier Le Bon1

1Psychological Medicine Laboratory, Campus Brugmann, Université Libre de Bruxelles, Brussels, Belgium, 2Department of Psychology/Brain and Creativity, University of Southern California, Log Angeles, CA, USA, 3Department of Psychiatry and Desautels Faculty of Management, McGill University, Montreal, QC, Canada and 4Clinic of Addictions, Brugmann Hospital, Université Libre de Bruxelles, Brussels, Belgium

*Corresponding author: Clinic of Addictions, Salle 72, C.H.U Brugmann, 4, place Van Gehuchten, 1020 Bruxelles, Belgium. Fax: +32-24772162; E-mail: xnoel@ulb.ac.be

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Abstract — Aim: Sober alcoholic abusers exhibit personality traits such as novelty-seeking (NS) and sensation-seeking, which overlap to a limited extent. In parallel, they also show impaired executive and decision-making processes. However, little is known about the specific and common cognitive processes associated with NS and sensation-seeking personality traits in detoxified sober alcoholic abusers. Methods: In these present studies, we have investigated the relationships between executive functioning/central executive of working memory (pre-potent response inhibition, manipulation stored in working memory), and decision-making under uncertainty and NS/sensation-seeking traits in such alcoholics. Results: Compared with healthy controls (n = 30, mean age = 40.2), and in agreement with previous studies, alcoholics (n = 30, mean age = 40.4) showed higher levels of both NS and sensation-seeking traits. Alcoholics were also disadvantaged with respect to (a) gambling tasks, as reported previously, and (b) a poor ability to manipulate information stored in working memory and inhibit pre-potent responses. Most importantly, regression analyses and mediation analyses measures showed that poor response inhibition and decision-making were associated with high NS behaviour. In addition, impaired decision-making and manipulation of stored information in working memory were associated with a high sensation-seeking trait. Conclusions: Overall, these results support the existence of specific links between cognitive executive functioning, decision-making under uncertainty and NS/sensation-seeking personality traits in individuals with alcoholism.

INTRODUCTION

Cross-sectional and longitudinal studies by a variety of self-reporting personality questionnaires show the importance of disinhibitory and/or strong appetitive processes, which is related to the vulnerability, the maintenance and relapse into alcohol abuse (for reviews, see Finn, 2002; Mulder, 2002; Acton, 2003). On the other hand, neurocognitive impairments have been identified in individuals with alcohol dependence, including deficits in the executive domain (e.g. pre-potent response inhibition, manipulation of information stored in working memory) and in processes involved in decision-making under uncertainty. Such a relationship between novelty-seeking (NS)/sensation-seeking and cognitive functioning has not been confirmed in all studies; since investigations which attempted to relate measures derived from self-reports questionnaires and performance measures of cognitive tests showed no relationship between these two parameters. This could be due to the misconceptions surrounding executive processes (e.g. concept of inhibition). Therefore, our primary aim in this study was to identify a potential relationship between two main facets of executive functioning (i.e. pre-potent response inhibition, co-ordination of dual-task), decision-making under uncertainty and both NS and sensation-seeking personality traits in sober alcoholic patients.

Cognitive-motivational theory of personality vulnerability to alcoholism describes impulsivity/NS and sensation/excitement-seeking as fundamental personality dimensions that are distinguished in terms of the motivation, emotional and cognitive processes that mediate or moderate vulnerability to alcohol use disorders (for a review, see Finn, 2002). For instance, a substantial body of research emphasized that exaggerated levels of NS are highly correlated with impulsivity and aggressivity (e.g. Finn et al., 2002) and excitement-seeking mediates alcohol use disorders (for reviews, see Finn, 2002; Mulder, 2002; Acton, 2003). In young alcoholics, high levels of disinhibited and appetitive personality traits, such as impulsivity, Boredom Susceptibility (BS), Thrill and Adventure (TAS)-seeking, excitement-seeking (Von Knorring et al., 1985, 1987; Sullivan et al., 1990; Finn et al., 2002); NS (Sullivan et al., 1990; Yoshino et al., 1994; Ball, 1996; Ball et al., 1998; Finn et al., 2002); and aggressiveness (Von Knorring et al., 1987; Babor et al., 1992) have been reported. High impulsivity sub-scale of NS, which is reflected by poor control of appetitive and aggressive impulses, difficulties in delaying gratification, acting without thinking and ‘increased’ activity, which is evident at 3 years of age, will predict the development of alcohol abuse in early adulthood (Kirisci et al., 2007; Tarter et al., 2007).

Sensation-seeking, defined as a strong need for varied, novel and stimulation experiences, and willingness to take risks for the sake of such experiences (Zuckerman, 1979), is another personality trait which is associated with high levels of alcohol and drug use (Andrucci et al., 1989; Conrod et al., 2008; Croissant et al., 2008). Numerous studies that focused on the relationship between sensation- and NS concluded that NS, defined either as a curiosity and exploratory need, and sensation-seeking, or as a need for exciting stimulation, are different traits (Byman, 2005; Mallet and Vignoli, 2007).

Interestingly, links were found between several executive functioning measures and behavioural ratings of approach tendencies and impulsivity (Cheung et al., 2004; Zermatten et al., 2005; Gay et al., 2008). For example, in the healthy populations, a relationship was found between performances on a classical decision-making task (i.e. the Iowa Gambling...
Task) and self-reported measures of impulsivity (Zermatten et al., 2005; Franken et al., 2008). On another decision-making task, which required participants to maximize their gain, the excitement seekers’ response strategy to the task was unrelated to whether the subjects were winning or losing (Finn, 2002). Interestingly, the task was performed by such individuals in a variable illogical fashion, rather than a predictive effect of choices based on recent events, even though that strategy did result in winning less money overall. Additionally, increased impulsivity, as measured by the Behavioral Inhibition System-11, was associated with poorer performance on some measures of inhibitory control (Cheung et al., 2004). In people with early onset of alcohol-related problems (see type II of alcoholism according to Cloninger et al., 1988), Finn et al. (2002) found a positive correlation between different measures of NS and performance of a motor response inhibition task (go/no-go paradigm) only in those individuals with low working memory storage capacity. Overall, such data emphasize the close relationship between NS/impulsivity, sensation-seeking traits on the one hand and cognitive processing (e.g. executive functioning and decision-making) on the other. The present study aims to investigate this relationship in a clinical population in which, both executive impairments and increased approach tendencies/impulsivity, are critical features of their alcoholism.

In the broadest sense, executive function is a general term for all processes recruited for managing and controlling cognition in situations where the routine selection of actions is unsatisfactory and is involved in the genesis of plans and willed actions (Norman and Shallice, 1986). According to Miyake et al. (2000), inhibition of pre-potent response, mental set shifting and information updating and monitoring represents three main executive functions. In addition, the capacity to co-ordinate dual-task represents a main central executive component of working memory (Baddeley, 2003) which is not related to any of these functions. Disturbances in these executive processes are one of the most consistent and predominant impairments in sober alcoholics (e.g. Giancola and Moss, 1998; Moselhy et al., 2001; Noël et al., 2001b). Among executive functions that are impaired in individuals with alcohol, the inhibition of pre-potent response inhibition has been identified by ourselves and others (e.g. Dao-Castellana et al., 1998; Noël et al., 2001a; Brokate et al., 2003; Hildebrandt et al., 2004; Oscar-Berman, 2004) as well as the monitoring of stored information in working memory (Ambrose et al., 2001; Noël et al., 2001a,b).

In addition to these main executive-related disorders, poor decision-making under uncertainty, i.e. numerous studies showed that sober alcoholics performed disadvantageously on a task (the Iowa Gambling task; Bechara and Martin, 2004) which simulates real-life decision-making in such a way that factors uncertainty of premises and outcomes, as well as reward and punishment. For this task, the alcoholics, who were either detoxified for a few weeks (Goudriaan et al., 2005; Noël et al., 2007) or had been alcohol abstinent for several years (Fein et al., 2004), both demonstrated poorer performance relative to controls. This reflected a certain obliviousness of the future consequences of their actions, and a behaviour that seems to be guided primarily by immediate prospects.

Thus, the aim of the present study was to further investigate, in sober alcoholics, the relationship between NS/impulsive and sensation-seeking personality traits and executive/decision-making cognitive functioning. We hypothesized that in recently detoxified patients with alcoholism, higher impulsivity/NS is associated with impaired pre-potent response inhibition. Sensation-seeking, which accounts more than NS for a part of variance of risk behaviour (Mallet and Vignoli, 2007) is expected to be closely associated with decision-making under uncertainty.

**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 University Hospital. The demographic data on the two groups are presented in Table 1.

**Alcoholic participants**

Thirty patients with alcohol dependence (APA, 1994) were recruited for this study from the Alcohol Detoxification Program of the Psychiatric Institute, Brugmann Hospital, Brussels, Belgium. Cognitive functions 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). All of the participants met Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) criteria for alcohol dependence (made by a board-certified psychiatrist) as assessed by the Structural Clinical Interview for DSM-IV. Exclusion criteria were other current DSM-IV Axis I diagnoses, a history of significant medical illness, head injury resulting in a loss of consciousness for >30 min that would have affected the central nervous system, the 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 β-carotene were assayed. For the detoxification regimen, both B vitamins as well as decreasing doses of sedative medication (diazepam) were administered. Current

**Table 1. Demographic and clinical variables of ALC and CONT**

<table>
<thead>
<tr>
<th>Variable</th>
<th>ALC (n = 30)</th>
<th>CONT (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>45.8 (9.5)</td>
<td>44.1 (8.9)</td>
</tr>
<tr>
<td>Gender (F/M)</td>
<td>12/30</td>
<td>12/30</td>
</tr>
<tr>
<td>Years of heavy drinking</td>
<td>17.05 (8.7)</td>
<td>–</td>
</tr>
<tr>
<td>Education (total years)</td>
<td>10.7 (2.0)</td>
<td>10.8 (2.5)</td>
</tr>
<tr>
<td>TQADC (in gram)</td>
<td>352.5 (240.5)</td>
<td>162 (12.8)</td>
</tr>
<tr>
<td>Number of prior detoxification treatments</td>
<td>4.5 (1.7)</td>
<td>4.3 (1.5)</td>
</tr>
<tr>
<td>Number of abstinence days</td>
<td>19.3 (2.5)</td>
<td>2.1 (1.4)</td>
</tr>
<tr>
<td>Cumulated diazepam doses during detoxification (mg)</td>
<td>737 (211)</td>
<td>–</td>
</tr>
<tr>
<td>MADRSb score</td>
<td>11.9 (9.8)</td>
<td>0.6 (0.7)</td>
</tr>
<tr>
<td>STAF–X1 score</td>
<td>43.4 (13.1)</td>
<td>30.8 (5.9)</td>
</tr>
<tr>
<td>STAF–X2 score</td>
<td>50.2 (10.4)</td>
<td>33.6 (8.1)</td>
</tr>
</tbody>
</table>

*Data are given as mean ± SD.

aTQADC, Total Quantity of Alcohol Daily consumed (P < 0.001).

bMontgomery Asberg Depression Rating Scale (P < 0.001).

cSTAI, State(X1)-Trait(X2) Anxiety Inventory Spielberger State Anxiety Inventory (P < 0.001).
clinical status was rated using the Montgomery Asberg depression scale (Montgomery and Asberg, 1979) and the Spielberger State Trait Anxiety Inventory (STAI Trait and State; Spielberger, 1983).

Control participants
Thirty healthy participants who were comparable to the alcohol group, 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 anyone who had met an Axis I psychiatric diagnosis assessed by the Structured Clinical Interview for DSM-IV; who had experienced a drug-use disorder during the year before enrolment in the study; or who had consumed >54 g/day 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 h.

Current clinical status
Current clinical status was rated with the Beck Depression Inventory (BDI; Beck et al., 1961) and the STAI (Spielberger, 1983). We excluded any control subject who had an Axis I psychiatric diagnosis assessed by the Structured Clinical Interview for 'DSM-IV' (First et al., 2002).

Personality traits assessment
One issue that restricts research into specific personality mechanisms involved in alcoholism is the wide range of different personality traits and measures used in different studies (Whiteside and Lynam, 2001).

NS, including its subscale Impulsiveness and Harm Avoidance (HA) were obtained using Cloninger’s Temperament and Character Inventory (TCI; Cloninger, 1993), a binary forced-response questionnaire containing 226 items, with no clues as to what could be considered as ‘favourable’ responses. The TCI includes both (4) Temperament and (3) Character dimensions. Both NS and HA are temperament dimensions. Temperament manifests early in life and involves pre-conceptual or unconscious learning. Character represents conceptual or insight-based learning of self-concepts, which mature in adulthood and are not linked to particular biological processes. Temperament initially motivates and biases learning, but Character modifies the significance and salience of perceived stimuli to which the person responds, so that both Temperament and Character development influence each other and motivate behaviour. NS reflects behavioural activation and would be associated with dopaminergic activity. It is defined as the tendency to respond actively to novel stimuli leading to the pursuit of rewards and escape from punishment. HA reflects behavioural inhibition and is supposedly linked to serotonergic activity and corresponds to the tendency towards an inhibitory response to signals of aversive stimuli leading to avoidance of punishment and non-reward.

The Disinhibition (DIS) (“I like wild, uninhibited parties”) and BS (“I get bored seeing the same old faces”) subscales of the Sensation-Seeking Scale (SSS; Zuckerman, 1979) served as indicators of excitement-seeking. In these studies, the DIS and BS were utilized, and not the Experience-Seeking and TAS subscales, also from the SSS, since research has indicated that the DIS and BS reflect an underlying subfactor of sensation-seeking with common genetic origins (Kooijmans et al., 1995). This will reflects excitement-seeking to a higher degree (Finn et al., 2000). The TAS would reflect low HA rather than excitement-seeking per se (Watson and Clark, 1984; Finn et al., 2000, 2002).

Cognitive assessment
Decision-making under uncertainty
The Iowa Gambling task (IGT; Bechara et al., 1994, 1997) involves four 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. However, at unpredictable points, the selection of a card is followed by a high penalty, so over a period of time, 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 over a period of time, these decks are advantageous. More specifically, the schedules for 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. In contrast, this discrepancy between reward and punishment in the advantageous decks (C’&D’) is rendered larger in the positive direction (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 IGT, 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.

Central Executive of Working memory (manipulation of stored information)
The alpha-span task (Belleville et al., 1998) investigates 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). A classical word-span task is first used to assess the span level of each subject, which represents a measure of the passive verbal storage in working memory (phonological loop, Baddeley, 1996). After the span measurement, the subject is asked to repeat word sequences in two different conditions: direct recall and alphabetical recall. In both conditions, the number of words to be recalled corresponds to the subject’s span minus one item. In the direct condition, the subject performs an immediate serial recall of ten sequences of words. In the alphabetical condition, the subject is asked to recall ten sequences of words in their alphabetical order. The subject’s performance is assessed by comparing the performance on alphabetical recall to that in serial recall. Moreover, a manipulation score is also derived for each individual subject as follows: [(score in direct condition – score in alphabetical condition)/direct condition] ×
Pre-potent response inhibition

The Hayling task (Burgess and Shallice, 1996) assesses the capacity to suppress (inhibit) a habitual response and was initially divided into two sections to examine both initiation and inhibition processes. The Hayling task consists of sentences in which the final words are omitted, but there is a particularly high probability of one specific response. The task consists of two sections (A and B), each containing 15 sentences. In section A (initiation), sentences are read aloud to the subject who has to complete the sentence with the missing word. In section B (response suppression), sentences are read to the subject who, on this occasion, has to complete the sentence, not with the expected word but with a word unrelated to the sentence. If at any time during this stage of the test, the subject gives a sentence completion rather than an unrelated word, he or she is told that the word was too related to the sentence and the task instructions are repeated. If a subject does not produce a word within 30 s, that trial is terminated and a response latency of 30 s was recorded. Different measures of responses suppression abilities are used in the analysis. First, there are responses that are sensible completions of the sentence, thus clearly violating the task instructions (three penalty points). For example, in the sentence ‘The captain wanted to stay with the sinking...’, the response ‘boat’ would yield a score of 3. Secondly, there are responses that are semantically connected to the sentence in some way (1 penalty point). Thirdly, there were those responses that were unrelated to the sentence, as required by the task instructions (0 penalty point).

Procedure

All alcoholic participants (ALCs) were inpatients admitted to the Clinic of Addictions for detoxification and treatment. Each patient had serious substance abuse problems which required professional intervention, which was the reason for their admission.

The duration of their abstinence at study time was >15 days in all cases. Each ALC was tested at the end of treatment, i.e. usually a day or two before discharge. Thus, at the time of testing, the ALCs were no longer in acute withdrawal or taking any medication to control withdrawal. ALCs were routinely checked for substance abuse during their treatment. They were also breathalyzed and subjected to urine toxicology screening for opiates, stimulants and marijuana, immediately before testing. Therefore, we can reasonably conclude that there was no use of substances during the entire period of abstinence.

The duration of abstinence, the number of times in treatment and the total number of years of abuse were obtained from interviews. The Onset of Problem Drinking was assessed as the mean score of five items (i.e. began using alcohol regularly, realized alcohol gave relief, first tried to stop using alcohol, family or friends said you had a problem with alcohol, first thought that you had a problem with alcohol).

The ethical review board of the CHU Brugmann approved the study (Ref.: CE 2009/88) and written informed consent was obtained.

Data analyses

For the data collected from the various neuropsychological tests, ANOVAs were performed to determine for which variables ALC and control participants (CONTs) differed significantly. Post hoc analyses were t-test with correction for multiple comparisons (Bonferroni’s method). Pearson’s correlations were used to evaluate the relationship between variables. In order to test the existence of a specific association between NS/impulsivity and pre-potent response inhibition on the one hand and between sensation-seeking and co-ordination of dual-task and decision-making under uncertainty on the other, multiple stepwise regression analyses were performed with personality traits as predictor and cognitive task performances as dependent variables (DVs). Finally, as additional analyses, we also tested if executive functioning acts as a mediator of the relationship between decision-making and, (a) NS, (b) sensation-seeking. We also tested the existence of a modifying effect in the alcohol group on the potential mediation effect of executive functioning. All statistical analyses were based on two-tailed tests of significance and were performed using the Statistical Package for the Social Sciences (SPSS) version 17.0 for Windows (Chicago: SPSS Inc.).

RESULTS

Demographics and current clinical status

A description of demographic variables, scores on the BDI and the STAI are presented in Table 1. ALC and non-ALC were similar in term of age (F(1,58) = 0.34; P = 0.57), years of education (F(1,58) = 0.003; P = 0.96) and of male/female ratio (χ²(1, 58) = 0.00; P = 1.00). However, patients were more depressed (F(1,58) = 39.4; P < 0.001) and reported higher levels of state and trait anxiety, F(1,58) = 7.61; P < 0.01; F(1,58) = 27.56; P < 0.001, respectively.

Personality measures

NS (impulsiveness, extravagance and disorderliness) and sensation-seeking (DIS and BS) were found significantly higher in ALC than in CONT (Table 2).

Cognitive measures

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 < 0.001, of group, F(1,58) = 9.99; P < 0.01. The repeated measures ANOVA yielded a significant interaction, F(4,55) = 3.6; P < 0.01, indicating that CONT performed better than ALC on the task at Stage 5 (Fig. 1).
**Table 2. Mean (SD) of personality traits in ALC and CONT**

<table>
<thead>
<tr>
<th>TCI</th>
<th>ALC (n = 30)</th>
<th>CONT (n = 30)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty-seeking</td>
<td>49.3 (21.3)</td>
<td>16.8 (4.5)</td>
<td>(F(1,58) = 6.64; P &lt; 0.001)</td>
</tr>
<tr>
<td>Exploratory excitability</td>
<td>5.5 (2.2)</td>
<td>5.5 (1.7)</td>
<td>(F(1,58) = 0; P = 1.000)</td>
</tr>
<tr>
<td>Impulsiveness</td>
<td>5.2 (2.4)</td>
<td>3.4 (1.9)</td>
<td>(F(1,58) = 10.5; P &lt; 0.001)</td>
</tr>
<tr>
<td>Extravagance</td>
<td>6.1 (2.0)</td>
<td>4.3 (2.1)</td>
<td>(F(1,58) = 11.7; P &lt; 0.001)</td>
</tr>
<tr>
<td>Disorderliness</td>
<td>5.1 (2.0)</td>
<td>3.6 (1.8)</td>
<td>(F(1,58) = 9.8; P &lt; 0.01)</td>
</tr>
<tr>
<td>Fear of uncertain</td>
<td>6.8 (2.4)</td>
<td>3.3 (2.4)</td>
<td>(F(1,58) = 32.4; P &lt; 0.001)</td>
</tr>
<tr>
<td>Shame/narcissus</td>
<td>4.7 (1.9)</td>
<td>3.2 (2.3)</td>
<td>(F(1,58) = 7.4; P &lt; 0.01)</td>
</tr>
<tr>
<td>Shyness with strangers</td>
<td>4.3 (2.5)</td>
<td>2.6 (2.3)</td>
<td>(F(1,58) = 7.8; P &lt; 0.01)</td>
</tr>
<tr>
<td>Fatigability</td>
<td>5.2 (2.6)</td>
<td>3.5 (2.7)</td>
<td>(F(1,58) = 6.3; P &lt; 0.01)</td>
</tr>
<tr>
<td>Reward-dependence</td>
<td>14.5 (3.9)</td>
<td>13.9 (4.3)</td>
<td>(F(1,58) = 0.4; P = 0.53)</td>
</tr>
<tr>
<td>Attachment</td>
<td>7.6 (1.8)</td>
<td>6.4 (2.1)</td>
<td>(F(1,58) = 5.4; P &lt; 0.05)</td>
</tr>
<tr>
<td>Dependence</td>
<td>4.4 (1.9)</td>
<td>4.6 (2.3)</td>
<td>(F(1,58) = 0.4; P = 0.50)</td>
</tr>
<tr>
<td>Persistence</td>
<td>2.6 (2.0)</td>
<td>2.7 (1.3)</td>
<td>(F(1,58) = 0.9; P = 0.77)</td>
</tr>
<tr>
<td>Sensation-seeking scale</td>
<td>5.2 (1.9)</td>
<td>5.0 (1.8)</td>
<td>(F(1,58) = 0.3; P = 0.579)</td>
</tr>
<tr>
<td>Disinhibition</td>
<td>5.8 (2.6)</td>
<td>3.1 (1.9)</td>
<td>(F(1,58) = 14.5; P = 0.000)</td>
</tr>
<tr>
<td>Boredom susceptibility</td>
<td>8.1 (3.3)</td>
<td>5.3 (1.3)</td>
<td>(F(1,58) = 12.4; P = 0.000)</td>
</tr>
</tbody>
</table>

**Table 3. Mean (SD) on cognitive performances in ALC and CONT**

<table>
<thead>
<tr>
<th>Cognitive task</th>
<th>ALC (n = 30)</th>
<th>CONT (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha-span task (working memory)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word-span size</td>
<td>4.7 (0.7)</td>
<td>4.9 (0.6)</td>
</tr>
<tr>
<td>Serial recall score</td>
<td>9.3 (0.8)</td>
<td>9.5 (0.6)</td>
</tr>
<tr>
<td>Alphabetic recall score(^a)</td>
<td>5.8 (2.1)</td>
<td>8.9 (1.1)</td>
</tr>
<tr>
<td>Manipulation score(^a)</td>
<td>62.8 (22.1)</td>
<td>94.4 (11.2)</td>
</tr>
<tr>
<td>Hayling task (response inhibition)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean RT initiation (s)(^a)</td>
<td>9.3 (2.6)</td>
<td>8.8 (1.5)</td>
</tr>
<tr>
<td>Mean RT inhibition (s)(^a)</td>
<td>83.4 (45.9)</td>
<td>49.8 (11.8)</td>
</tr>
<tr>
<td>Total penalty score(^a)</td>
<td>8.7 (3.7)</td>
<td>1.3 (0.9)</td>
</tr>
</tbody>
</table>

\(^{a}\)P < 0.001.

**Alpha-span task performance**

The two-way ANOVA for repeated measures with group and type of recall (serial, alphabetical) as factors revealed a main effect of type of recall, \(F(1,58) = 87.6; P < 0.001\), of group, \(F(1,58) = 39.9; P < 0.001\), and a significant interaction of the two factors, \(F(1,58) = 47.1; P < 0.001\), indicating that ALC made more errors to recall words in alphabetical than in serial order than CONT (Table 3).

**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 \([F(1,58) = 169.4; P < 0.001]\), of group \([F(1,58) = 16.1; P < 0.001]\) and a group by type of condition interaction \([F(1,58) = 13.9; P < 0.001]\). ALCs were significantly slower than CONT to give an answer when the task requiring to complete the sentences with a semantically unrelated word (section B) but not on section A \((P < 0.001)\) where the semantically related word is needed (section A). Regarding the responses quality, ALC made more penalty errors than CONT \([t(1,58) = 10.6; P < 0.001]\) (Table 3).

**Relationship between personality measures and cognitive performance in participants**

Correlations between personality measures and cognitive performance are presented in Table 4. After Bonferroni’s correction, there were significant correlations in the alcoholic group between score of NS and IGT \((P < 0.05)\) and Hayling test \((P < 0.05)\), as well as between score of sensation-seeking and Alpha span \((P < 0.05)\).

The regression analysis showed that the Hayling score was the only significant predictor of the NS score \((R^2 = 0.58, \beta = 0.76, P < 0.001)\) and that the manipulation score of the alpha-span task was the only significant predictor of the sensation-seeking score \((R^2 = 0.15, \beta = 0.39, P < 0.05)\).

**Additional analyses**

On the basis of the results highlighted by correlational and stepwise regression analyses, we carried out mediation and moderation analyses with scores on the Hayling task as a mediator of the relationship, on both IGT and self-reported sensation-seeking and NS.

Mediation of executive functioning on the relationship between decision-making and (a) NS, (b) sensation-seeking

There were four stages of regression analyses (Baron and Kenny, 1986). First, the independent variable (IV) must predict the mediator (M). Thirdly, the M must predict the DV, while controlling for the IV. Lastly, the procedures can only be achieved if, while controlling for M, the effect of the IV on the DV is zero.

(a) The IV was a NS score, with total score on the IGT as the DV and score on the Hayling as the M. Results showed that (i) NS predicted score on the IGT, \(\beta = -0.57, SE = 0.12, t(59) = -4.50; P < 0.001\); (ii) NS
predicted Hayling score, $\beta = 0.15$, SE = 0.02, $t(59) = 8.91$; $P < 0.001$; (iii) Hayling predicted IGT while controlling the effect of novelty on IGT, $\beta = -1.77$, SE = 0.91, $t(59) = -2.01$; $P < 0.05$ and (iv) novelty did not predict IGT while controlling for Hayling, $\beta = -0.28$, SE = 0.19, $t(59) = 1.52$; $P = 0.13$. These results are indicative of a complete mediation of Hayling score on the effect of NS on score on total score on the IGT.

(b) The IV was the sensation-seeking score, with total score on the IGT as the DV and score on the Hayling as the M. Results showed that (i) sensation-seeking predicted score on the IGT, $\beta = -0.57$, SE = 0.12, $t(59) = -4.50$; $P < 0.001$; (ii) sensation-seeking predicted Hayling score, $\beta = 0.15$, SE = 0.02, $t(59) = 8.91$; $P < 0.001$; (iii) Hayling predicted IGT while controlling the effect of sensation on IGT, $\beta = -2.25$, SE = 1.29, $t(59) = -1.74$; $P = 0.09$ and (iv) sensation did not predict IGT while controlling for Hayling, $\beta = -0.82$, SE = 0.46, $t(59) = -1.80$; $P = 0.08$. These results indicate that Hayling score only partially mediates the effect of sensation-seeking score on total score on the IGT.

Moderation of the alcohol group on the mediation of dominant response inhibition on the relationship between NS and decision-making

There were four stages of regression analyses. First, the moderator (Mo) must predict the IV. Secondly, the Mo must predict the DV. Thirdly, the Mo must predict the M. Lastly, the product of IV×Mo and M×Mo must predict the DV.

The IV was the NS score, with total score on the IGT as the DV, score on the Hayling as the M and groups as the Mo. Results showed that (a) group predicted score on the IGT, $\beta = 22.37$, SE = 5.81, $t(59) = 3.84$; $P < 0.001$; (b) group predicted Hayling score, $\beta = -7.67$, SE = 0.67, $t(59) = -11.37$; $P < 0.001$; (c) group predicted NS, $\beta = -34.17$, SE = 3.94, $t(59) = -8.67$; $P < 0.001$; (iv) IV×Mo predict IGT, $\beta = -0.59$, SE = 0.16, $t(59) = -3.62$; $P < 0.001$, and M×Mo predict IGT, $\beta = -2.98$, SE = 0.69, $t(59) = -4.52$; $P < 0.001$. These results indicate that group is a moderator of the mediation of dominant response inhibition on the relationship between NS and decision-making.

DISCUSSION

In this study, we have investigated the links between executive/decision-making functions and personality/temperamental in recently detoxified individuals with alcoholism (ALC), since they are frequently reported as being at a higher risk to become an alcoholic and to relapse into alcoholism.

Sober alcoholic patients who had been recently detoxified showed higher levels of NS/impulsiveness and of sensation/excitement-seeking/excitement, which were weakly correlated to each other, and were associated with poor capacity to inhibit pre-potent response and to manipulate information stored in working memory, respectively. Both correlational and regression analyses showed that NS and sensation-seeking are highlighted by specific cognitive determinants. Poor inhibition of pre-potent response was associated with greater NS in alcoholics and a poorer capacity to manipulate information stored in working memory, which is associated with sensation-seeking.

First, there was a group difference with respect to personality traits and cognitive processes: higher levels of NS (e.g. Le Bon et al., 2004) and of sensation-seeking (e.g. Zuckerman and Neub, 1979) in ALC compared with CONT. The alcoholic group performed poorly on tasks which assessed decision-making under uncertainty (e.g. Noël et al., 2007), manipulation of information stored in working memory (e.g. Ambrose et al., 2001) and on the task assessing the capacity to inhibition pre-potent response (e.g. Noël et al., 2001b; Hildebrandt et al., 2004; Goudriaan et al., 2005).

The main result of this article was that these two traits have distinct cognitive determinants.

First, we found that high level of NS (impulsivity) in alcoholics was associated with low performance on task assessing pre-potent response inhibition (e.g. Hayling task). The association between NS and dominant response inhibition is in agreement with the theory that this personality trait encompasses abnormal appetitive/approach tendency and difficulty in inhibiting or modulating those behaviours (Patterson and Newman, 1993; Newman and Schmitt, 1998; Finn et al., 2002). Also supporting this association, Finn et al. (2002) found a positive correlation between different measures of NS and performance of a motor response inhibition task (go/no-go paradigm) particularly in those individuals with a low storage working memory capacity. More recently, one study emphasized, in a non-clinical population, that urgency (a facet of impulsivity, Whiteside, 2001) was specifically related to errors in pre-potent response inhibition (Gay et al., 2008). Also, impulsivity has been associated with a decreased ability to alter (inhibit) choice behaviour in response to fluctuations in reward contingency (Franken et al., 2008). These findings, together with our data, reinforce the idea that the capacity to inhibit/suppress pre-potent response is a cognitive component of the tendency to seek novelty and/or to weakly regulate bottom-up processes.

Furthermore, the mediation analyses results suggest that executive functioning underlies the effect of personality traits
on decision-making. More specifically, we found that dominant response inhibition mediates the effect of NS on decision-making under uncertainty. Importantly, we also observed that this group is a moderator of this mediation effect. In other terms, this result suggest that, on the one hand, low dominant response inhibition capacity of individuals with alcoholism would mediate the relationship between high NS and impaired decision-making under uncertainty. On the other hand, in CONTs, efficient dominant response inhibition capacity would mediate the relationship between ordinary level of NS and advantageous decision-making under uncertainty.

Furthermore, the alcoholics’ ability to manipulate information stored in working memory significantly predicts the intensity of sensation-seeking. With respect to the influence of working memory on the tendency to seek sensations, our results suggest that a better capacity to manipulate information stored in working memory tends to attenuate boredom, thus making the need for more activity less preponderant. Another strong support for this idea comes from a recent study showing a negative correlation between event-related activities in regions classically dedicated to working memory (i.e. the dorsal anterior cingulate, the lateral prefrontal cortex and parietal areas; Gray et al., 2005).

The relationship between high impulsivity/poor cognitive inhibition and alcoholism is still a debated issue. On the one hand, these personality and cognitive traits may predominantly represent a predisposing factor to become addicted to alcohol, in that impulsive individuals not only drink more alcohol, but do so in a manner that is more likely to lead to problems (Cloninger et al., 1988; Masse and Tremblay, 1997; Finn et al., 2000; Finn, 2002; Finn et al., 2002). On the other hand, impulsivity might be strongly increased by the chronic consumption of alcohol itself, notably through its enhanced motivational properties. Indeed, psychobiological theories assume that the development of alcoholism and impulsivity could be the consequence of two interconnected phenomena: (a) an excessive incentive motivation for alcohol making a drink very ‘needed’ (Robbinson and Berridge, 1993; 2003; Robbins and Everitt, 2002) and (b) a inhibitory dysregulation impacting control attempts (for a review, see Jentsch and Taylor, 1999; Lubman et al., 2004). Repeated exposure to drugs of abuse (including alcohol) can produce the progressive enhancement of the incentive qualities of the drug (e.g. Robinson and Berridge, 1993, 2003).

What do these results bring us in terms of clinical relevance? Several studies suggested that sensation-seeking and NS traits represent prognostic factors of alcohol relapse (e.g. Marra et al., 1998). In addition, it has been shown that poor performance of working memory and dominant response inhibition at the end of a 3-week detoxification period increase the likelihood of relapse during the next 3 months (Noël et al., 2002). Interestingly, according to Tiffany (1990), drug-use behaviour in the addict represents activity, which is largely dependent on automatic processes. Furthermore, non-automatic (controlled or executive) cognitive processes are needed to impede or block a drug-use action plan and consequently to maintain abstinence. In other words, the existence of executive function deficits in alcoholics, as evidenced in the present study, could affect the capacity to maintain abstinence. Of course, further longitudinal investigations are needed to explore whether the relationship between impulsivity relapse is mediated by working memory and response inhibition deficits.

There are certain limitations to the generalization of these results which include the relatively small groups for multivariate analyses. Furthermore, the alcohol subjects were seeking help, which (a) may bias them as being representative among their peers, (b) and that the inclusion of alcoholic patients receiving treatment after 3 weeks may constitute a selection bias, with the most cognitive impaired patients being unable to remain in treatment for long periods. Another possible bias is that chronic alcohol abuse may induce psychiatric states that modify the assessment of personality (Post, 1975; Wise and Bozarth, 1987) and this would lessen the interest of such procedures. Finally, the presence of externalizing symptoms (not just disorders) might impact on cognitive processing. As a consequence, the generalization of our findings must be taken with caution and more research which assesses the degree of elevations in externalizing symptoms is needed.

In summary, we have found that alcoholics detoxified for 2–3 weeks showed traits for impulsiveness/NS and sensation-seeking together with impaired capacity to decide advantageously in situations under uncertainty, to inhibition of the pre-potent response and to manipulation information stored in working memory. The study of this relationship between these cognitive and personality traits has highlighted that in alcoholic subjects, poor decision-making can be predicted by high level of NS through impaired pre-potent response inhibition. In addition, the capacity to manipulate information stored in working memory appeared to be closely related to the proneness of alcoholics to seek sensations.

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