INTRODUCTION

Alcohol intoxication is often associated with violent crimes, suicide, the spread of sexually-transmitted diseases, injuries and automobile accidents (Pernanen, 1976; Ericksen and Trocki, 1992; Cherpitel, 1993, 1999). A common assumption is that at least some of these effects are due to alcohol's tendency to produce impulsive behaviour (Critchlow, 1986). Two types of impulsivity can be identified (Brunner and Hen, 1997): motor impulsivity is the failure to inhibit behaviour and cognitive impulsivity is the inability to consider future events or, more specifically, the preference for a small, immediate reward over a large, delayed reward (Ainslie, 1975). Empirical or, more specifically, the preference for a small, immediate reward over a large, delayed reward. To test the predictions of alcohol myopia theory, participants completed a standard version of the task or one containing cues which impelled the impulsive choice (i.e. preference for the small, immediate reward). Participants also completed a personality measure of impulsivity and the go/no-go task, which assesses motor impulsivity. Results: Intoxicated participants tended to discount delayed rewards at lower rates than sober participants, and blood alcohol level was inversely correlated with delay discounting. The impelling cues did not moderate the effects of alcohol on delay discounting. Conclusions: Alcohol intoxication does not always increase cognitive impulsivity and may lead to more cautious decision-making under certain conditions.

Alcohol increases cognitive impulsivity in rats (Poulos et al., 1998), but does not influence discounting of delayed monetary rewards in humans (Richards et al., 1999). A possible explanation for this discrepancy is that alcohol-induced impulsivity is moderated by alcohol myopia (Steele and Josephs, 1990). According to this theory, alcohol intoxication restricts information processing, causing an individual to extract meaning solely from the most salient cues in their environment. If cues provoking an impulsive choice are more salient than cues inhibiting that choice, alcohol increases impulsivity. In contrast, if either or both of the impelling and inhibiting cues are weak, alcohol myopia does not influence responding. Alcohol myopia theory may explain why Richards et al. (1999) failed to find an effect of alcohol on delay discounting because the two response choices (e.g. $5.00 now or $10.00 in 365 days) were both weak cues. Practice effects may also have masked any treatment effects, because participants received five exposures to the delay-discounting task (practice, pre-placebo, post-placebo, pre-alcohol and post-alcohol). Finally, trait impulsivity affects responding in that personality measures of impulsivity correlate with performance on the delay-discounting task (Richards et al., 1999), with alcohol use and with alcohol-related problems (Nagoshi et al., 1991; Grau and Ortet, 1999). Even rats exhibit individual differences in responsiveness to alcohol in tests of cognitive impulsivity (Poulos et al., 1998).

The purpose of the present study was to examine the factors affecting cognitive impulsivity in intoxicated individuals. We hypothesized that intoxicated participants would make more impulsive choices only when the cues impelling impulsive behaviour were salient. Cognitive impulsivity was measured in sober, intoxicated and control (i.e. no drink) participants using the delay-discounting task; cue salience was manipulated by presenting one of the response choices in bold, as this manipulation successfully changes the direction of responding in intoxicated participants (MacDonald et al., 2000). To test whether trait impulsivity and cognitive impulsivity were correlated, participants completed a questionnaire measure of impulsivity prior to completing the task. We also assessed the
relations among cognitive impulsivity, blood alcohol level (BAL) and self-reported desire to consume more alcohol, because cognitive impulsivity predicts voluntary consumption of alcohol in rats (Poulos et al., 1998), and alcohol dose-dependently increases subjective reports of drug liking and the desire to ingest more alcohol in humans (Kirk and de Wit, 2000). Finally, we measured motor impulsivity using a go/no-go task in order to compare the effects of alcohol on two different types of impulsivity (i.e. cognitive and motor).

SUBJECTS AND METHODS

Participants

Participants were 76 male undergraduate students at Queen’s University, who were of legal drinking age, and reported on a pre-test that they consumed alcohol at least once per month. Females were not tested due to the potential health consequences of consuming alcohol while pregnant, although some researchers include female participants after a negative pregnancy test. Participants received $10 plus the money they won in the delay-discounting task. The research was approved by the Ethics Committee, Department of Psychology, Queen’s University, and all participants gave written informed consent.

Dependent measures

Zuckerman–Kuhlman Personality Questionnaire (ZKPQ). The impulsiveness sensation seeking scale (ImpSS) of the ZKPQ (Zuckerman et al., 1993) consists of 19 items regarding a lack of planning and the tendency to act impulsively. The ImpSS was chosen because it is a significant predictor of risk behaviours (e.g. drug use and gambling) in college students (Zukerman and Kuhlman, 2000), but does not contain items relating to alcohol consumption, thereby reducing the possibility that alcohol use will act as a confound.

Delay discounting. A computerized version of the delay-discounting task (Mitchell, 1999) was presented on an IBM ThinkPad. Participants were presented with a series of hypothetical choices between the ‘standard’ and the ‘alternative’ item. The standard item was $10.00 available after one of six delays (0, 7, 30, 90, 180 or 365 days). The alternative item was an amount of money ($0.01, $0.25, $0.50, and further amounts increasing in 0.50 increments up to $10.50) available after 0 days (i.e. at the end of the session). Standard and alternative items were presented, without replacement, in a random order. The order in which the standard and alternative items were presented within each question was also randomized. For each participant, an indifference point was determined for each of the six delays. The indifference point is the value of the alternative (the immediate reward) at which the preference switches from the delayed to the immediate reward. Usually, the indifference point is discrete, but when it was not, it was defined as the point midway between the lowest value of the alternative at which the participant chose the alternative for two consecutive, descending values and the highest value of the standard for which the participant chose the standard for two consecutive ascending values.

Participants received the following verbal instructions: ‘You will have the opportunity to choose between different amounts of money available after different delays. The test consists of about 140 questions. Just indicate the alternative you prefer by pressing the appropriate key on the keyboard and then press enter. If you press the wrong key by mistake, simply press backspace and retype your answer. At the end of the session, one of the choices you made will be selected at random and you will receive whatever choice you made on that question and at the time stated in the question. So, if on that trial, you selected an immediate amount of money, you will receive the money in cash at the end of the session. If you selected the delayed money, the money will be placed in an envelope with your name on it and will be available to you when the time has elapsed.’ Participants were also informed that this money was in addition to the $10 they would receive for their participation in the study.

In the impelling cue condition, the alternative item was presented in bold and the instructions were altered to further impel an impulsive choice. When informing participants that one of their choices would be selected at random at the end of the session, the experimenter only described the outcome of selecting the alternative item on that choice, by saying: ‘So, for example: if on that trial, you selected an immediate amount of money, you will receive the money in cash at the end of the session.’

Go/No-Go. The go/no-go task (Owen et al., 1991) is a measure of motor impulsivity. A series of 18 characters (letters and digits) is flashed in the centre of a screen for 300 ms per character, at 900 ms intervals. Participants respond by pressing the space bar as quickly as they can when they see a specified stimulus (letters or digits) and withholding responses when presented with the other stimulus. Midway through the task, the target stimulus is switched and the participant must respond to the other stimulus. Measures include response reaction time, errors of commission (responding to an incorrect stimulus) and errors of omission (failing to respond to the specified stimulus).

Drug Effects Questionnaire (DEQ). The DEQ (Kirk and De Wit, 2000) is a self-report measure of alcohol’s effects and the desire to consume more alcohol. A modified version of the DEQ was employed, using three of the four scales. Each scale is a visual analogue scale 100 mm in length. The scales consist of ratings of ‘feel’ effects, ‘like’ effects and ‘want more’. The left ends of these scales are labelled ‘not at all’ (or ‘dislike a lot’) for ratings of ‘like’ effects. The right ends of these scales are labelled ‘a lot’ (or ‘very much’) for ratings of ‘want more’.

Design and procedure

Participants first completed the ZKPQ. Participants were randomly assigned to the intoxicated, placebo or sober condition. Within each condition, half the participants received the original version of the delay-discounting task and half received the impelling cue version. Sober participants completed the dependent measures and were debriefed.

Participants in the intoxicated condition were weighed and then received 0.7 g of alcohol/kg body weight divided into three alcoholic drinks. The drinks contained one part alcohol to two parts Wink soda. Participants in the placebo condition were also weighed and then consumed three non-alcoholic beverages containing one part soda water and two parts Wink soda. The rims of the glasses were dipped in alcohol and 5 ml of alcohol was placed on the surface of each placebo drink (MacDonald et al., 2000). Intoxicated and placebo participants consumed each drink within 2 min, with an 18 min rest period
between drinks. Twenty minutes after the final beverage, participants completed the dependent measures. BAL measures were obtained using a breathalyser and participants were then fully debriefed.

Data analysis

Delay discounting is best supported by a hyperbolic function (Green et al., 1999; Richards et al., 1999). Therefore, to assess the rate of discounting of delayed rewards, the curvilinear equation fitting function of SigmaPlot was used to fit each participant’s indifference points to the hyperbolic equation: 

\[ V = \frac{A \cdot t}{(1 + kD)} \]

Where \( V \) is the current, subjective value of the delayed reward, \( A \) is the amount of the delayed reward, \( D \) is the delay to the reward and \( k \) is a free parameter representing the rate of devaluation of the delayed reward. The fit of the hyperbolic model to individual participants’ data was evaluated based on values of \( t \) (the ratio of the parameter estimate to its standard error), with \((n - p)\) degrees of freedom, where \( n \) is the number of data points (6) and \( p \) is the number of free parameters (1). A value of \( t \) less than the critical value of \( t \) for \( P < 0.05 \) indicates that the parameter estimate is not an adequate fit for the data. Fit to the hyperbolic model across conditions was compared by means of a chi-squared test and between specific conditions using Mann–Whitney \( U \) tests, owing to the skewness of the \( r^2 \) values and the unequal group sizes.

The distribution of \( k \) values was extremely positively skewed and leptokurtic and the group variances were significantly heterogeneous. Therefore, a log-transformation \( [\log_{10}(k + 0.0001)] \) was computed before performing the analyses. Median indifference points with interquartile ranges are presented, because distributions of some of the indifference points were not normal. There were no significant differences between sober and placebo participants in mean log-transformed \( k \) values in either the standard or the impelling cue condition, leaving 10 participants in this group.

A two-way ANOVA was conducted to compare the effects of drink (alcohol or no-alcohol) and the cue salience manipulation (standard or impelling cue) in the delay-discounting task on log-transformed \( k \) values. A univariate ANOVA was computed to examine the effect of the delay-discounting condition on log-transformed \( k \) values, with BAL as a covariate. The effect of alcohol on go/no-go performance was examined by way of a two-tailed independent samples \( t \)-test. Finally, Pearson correlations were conducted to assess the relations among different measures of impulsivity.

Two participants in the alcohol, standard cue condition were inadvertently not administered the ZKPQ. Additionally, delay-discounting data were lost for one participant in the placebo, standard delay-discounting condition, leaving 10 participants in this group.

RESULTS

Blood alcohol levels (BALs)

Participants in the impelling cue condition had significantly lower mean BALs than participants in the standard condition \( \chi^2(35) = 4.63, P < 0.001 \) (see Table 1, which also contains the various test scores).

Delay discounting

Adequacy of the hyperbolic model. The median \( k \) values and correlation coefficients \( (r^2) \) for the goodness of fit of the hyperbolic equation to the participants’ indifference points for each group are presented in Table 2. There was a significant difference in the percentage of participants showing a lack of fit to the hyperbolic model in each group [standard condition: alcohol = 35%, placebo = 36%, sober = 0%; impelling cue condition: alcohol = 25%, placebo = 20%, sober = 25%; \( \chi^2(5, N = 462) = 11.12, P < 0.05 \)]. The hyperbolic model provided a significantly worse fit to the data for the placebo and alcohol participants in the standard condition, than to the data for the sober participants in the same condition (Mann–Whitney \( U = 13, P < 0.01 \) and \( U = 26, P < 0.01 \), respectively).

<table>
<thead>
<tr>
<th>Condition</th>
<th>( k )</th>
<th>( r^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.0056 (0.0010–0.0115)</td>
<td>0.75 (0.11–0.89)</td>
</tr>
<tr>
<td>Placebo</td>
<td>0.0065 (0.0022–0.0604)</td>
<td>0.79 (0.09–0.88)</td>
</tr>
<tr>
<td>Sober</td>
<td>0.0081 (0.0017–0.0158)</td>
<td>0.95 (0.83–0.97)</td>
</tr>
<tr>
<td>Impelling cue condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.0062 (0.0011–0.0170)</td>
<td>0.76 (0.45–0.93)</td>
</tr>
<tr>
<td>Placebo</td>
<td>0.0099 (0.0027–0.0278)</td>
<td>0.86 (0.43–0.95)</td>
</tr>
<tr>
<td>Sober</td>
<td>0.0087 (0.0024–0.0410)</td>
<td>0.64 (0.43–0.91)</td>
</tr>
</tbody>
</table>

Median delay-discounting parameters \( (k) \) and coefficients of determination \( (r^2) \) for the hyperbolic equation for each group in the two delay-discounting conditions (interquartile ranges in brackets) are given.

Table 1. Participant scores

<table>
<thead>
<tr>
<th>Condition</th>
<th>( n )</th>
<th>ImpSS (ZKPQ)</th>
<th>BAL (%)</th>
<th>DEQ, ‘want more’</th>
<th>DEQ, ‘like’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>17</td>
<td>10.53 (2.48)</td>
<td>0.074 (0.126)</td>
<td>6.42 (2.78)</td>
<td>7.25 (1.88)</td>
</tr>
<tr>
<td>Placebo</td>
<td>11</td>
<td>10.82 (2.75)</td>
<td>0.000 (0.000)</td>
<td>8.29 (1.25)</td>
<td>7.27 (1.53)</td>
</tr>
<tr>
<td>Sober</td>
<td>9</td>
<td>11.44 (4.72)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Impelling cue condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol</td>
<td>20</td>
<td>13.30 (4.76)</td>
<td>0.056 (0.011)</td>
<td>5.49 (3.09)</td>
<td>7.21 (1.98)</td>
</tr>
<tr>
<td>Placebo</td>
<td>11</td>
<td>12.10 (3.76)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sober</td>
<td>10</td>
<td>12.10 (3.76)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Sample sizes (\( n \)), impulsiveness sensation seeking scores (ImpSS), blood alcohol levels (BAL), and ratings from the Drug Effects Questionnaire (DEQ). Values are means (± SD).
The alcohol group discounted delayed rewards less steeply than the no-alcohol group, although this difference was not statistically significant [mean ± SD: standard condition: alcohol = –2.49 ± 0.90, no alcohol = –2.19 ± 0.81; impelling cue condition: alcohol = –2.40 ± 1.05, no alcohol = –2.03 ± 0.58; \(F(1,71) = 2.906, P = 0.093\)]. There was no significant effect of cue salience manipulation and no interaction between drink and the delay-discounting condition. One participant in the alcohol/impelling cue condition had an extremely high discounting parameter \(k = 1.0189\), which was 7.44 SDs away from the mean. Due to the small sample size, such an extreme value would have had a pronounced influence on the data. Furthermore, there was a significant negative correlation between log-transformed \(k\) values and BAL across both alcohol groups (Pearson correlation, \(r = –0.377, P < 0.05\)), indicating that participants with higher BALs discounted delayed rewards less steeply.

Figure 1 shows that the indifference points were higher in the alcohol than the no-alcohol condition (binomial test, \(P = 0.063\)). This finding provides further support for the notion that alcohol intoxication reduced the tendency to discount delayed rewards. The difference between median indifference points for the two groups approached significance at the 30-day delay only (Kruskal–Wallis, \(\chi^2 = 3.254, P = 0.071\)). In order to partial out any effects of BAL, a univariate ANOVA of the log-transformed \(k\) values was computed, with the delay-discounting condition (standard or impelling cue) as the fixed factor and BAL as a covariate. In this analysis, the delay-discounting condition had no significant effect on log-transformed \(k\) values.

Go/No-Go

Errors of omission on the go/no-go were very uncommon (mean ± SD = 0.26 ± 0.62), and therefore not included in the analysis. There was no significant effect of drink (alcohol or no-alcohol) on errors of commission (mean ± SD: alcohol = 3.97 ± 2.62, no-alcohol = 3.72 ± 1.62) or on reaction time (mean ± SD: alcohol = 402.8 ± 41.5 ms, no-alcohol = 396.0 ± 35.4 ms).

Correlations among measures of impulsivity

There was no correlation between ImpSS and delay discounting in either the alcohol or no-alcohol conditions (Pearson correlations, \(r = –0.170\) and \(r = –0.163\), respectively). However, in the alcohol group, there was a significant positive correlation between log-transformed \(k\) values and errors of commission on the go/no-go task (Pearson correlation, \(r = 0.420, P < 0.01\)). A median split was performed to divide participants into those who made few ('low') or many ('high') errors of commission. A two-way ANOVA (errors of commission: low or high × drink, alcohol or no-alcohol) was computed, with log-transformed \(k\) values as the dependent variable. Participants who were high on errors of commission discounted delayed rewards at a higher rate than participants who were low on errors of commission \(F(1,69) = 9.75, P < 0.05\) and there was an interaction between errors of commission and drink \(F(1,69) = 6.90, P < 0.05\). The effect of drink approached significance \(F(1,69) = 3.31, P = 0.07\). These findings are illustrated in Fig. 2. \(t\)-tests revealed that, in the group low on errors of commission, rates of discounting were higher in the no-alcohol than in the alcohol group \(t(27.72) = –2.93, P < 0.01\).

In the no-alcohol condition, mean reaction time in the go/no-go task correlated positively with ImpSS scores on the ZKPQ (\(r = 0.424, P = 0.01\)) and with errors of commission on the go/no-go task (\(r = 0.325, P = 0.05\)). There was no correlation between delay discounting in intoxicated participants and ‘want more’ scores on the DEQ. However, there was a significant positive correlation between BAL and ‘want more’ ratings (\(r = 0.281, P < 0.05\)).

DISCUSSION

Although alcohol did not significantly affect delay discounting, it appeared to reduce cognitive impulsivity in that...
no-alcohol participants discounted delayed rewards at higher rates than intoxicated participants. Furthermore, BALs were inversely correlated with rates of delay discounting. These findings contradict evidence that alcohol has no effect on delay-discounting in humans (Richards et al., 1999). One explanation is that Richards et al.’s participants completed the delay-discounting task five times, possibly establishing a stable pattern of responding across the alcohol and placebo sessions. The current findings also contradict reports that alcohol increases cognitive impulsivity in rats (Poulos et al., 1998), but there are a number of differences between rat and human versions of the task. For example, rats both select and receive the rewards while intoxicated, and they receive each reward before making the next response. They also receive real, food rewards, rather than hypothetical, monetary rewards, that may have a different significance for each person. Indeed, drug addicts will discount drug rewards at higher rates than monetary rewards (Petry, 2001).

The reduction in cognitive impulsivity when intoxicated could be explained by the alcohol myopia theory in that aspects of the experimental environment (e.g., presence of the experimenter, knowledge that the experimenter would later view the data), may have acted as salient inhibiting cues, reducing impulsive behaviour in intoxicated individuals. This notion is supported by the finding that intoxicated participants who made few errors of commission on the go/no-go task also responded less impulsively on the delay-discounting task, only when intoxicated. That is, perhaps intoxicated participants who were most aware of inhibiting cues in the environment were more cautious on both measures of impulsivity.

Contrary to the initial prediction, the impelling cue manipulation did not moderate the effects of alcohol on delay discounting. It is possible that the impelling cues were not salient enough to influence participants’ responses, particularly because both possible outcomes were presented simultaneously. In contrast, in the real world, as well as in the study by MacDonald et al. (2000), cues regarding the delayed reward or negative outcome are not available during decision-making, unless the individual removes his attention from the current (i.e. more salient) environmental cues.

BALs correlated significantly with ‘want more’ ratings, confirming that alcohol dose-dependently increases subjective reports of drug liking and the desire to consume more alcohol (Kirk and de Witt, 2000). Given this, further assessment of the effects of alcohol intoxication on preference for alcohol rewards would further our understanding of how alcohol consumption is perpetuated within a drinking session, and would have important implications for theories of how alcohol misuse is initiated and maintained.

Finally, trait impulsivity, as assessed by the ImpSS, was not associated with cognitive impulsivity on the delay-discounting task, even though it predicts alcohol use and other risk-taking behaviours in college students (Zuckerman and Kuhlman, 2000). The relation between personality measures of impulsivity and performance on behavioural tasks, however, depends on the specific questionnaire (Mitchell, 1999; Richards et al., 1999). In the current study, high scores on the personality measure were associated with slow responses on the go/no-go task, suggesting that impulsiveness sensation-seeking reflects motor impulsivity, rather than cognitive impulsivity.

In conclusion, the current study found that, contrary to common assumptions, alcohol intoxication in humans was associated with more cautious or less impulsive responding. Additionally, intoxicated participants were more likely to show lack of fit to the hyperbolic model, suggesting that they responded less consistently on the delay-discounting task. The delay-discounting paradigm could be further modified to test the predictions of alcohol myopia more effectively. For example, manipulations that increase inhibition conflict by using larger sums of money (Steele and Southwick, 1985) would be expected to increase the likelihood that alcohol will induce cognitive impulsivity. To enhance cue salience, participants’ attention could be drawn to the consequences of winning the immediate reward prior to completing the delay-discounting task. A further test of the alcohol myopia theory would involve assessing the effect of inhibiting cues on delay discounting. The theory would predict that, when faced with strong, salient, inhibiting cues, intoxicated individuals will discount delayed rewards less steeply than sober participants.

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REFERENCES


