CRAVING AND COGNITIVE BIASES FOR ALCOHOL CUES IN SOCIAL DRINKERS

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Abstract — Aims: To assess whether cognitive biases for drug-related cues are associated with subjective craving and behavioural indices of drug-seeking behaviour, as predicted by incentive models of addiction. Methods: Fifty social drinkers took part in a laboratory study in which their subjective craving and cognitive biases for alcohol cues were assessed, before they completed a progressive ratio operant task for alcohol (beer) reinforcement. Results: Social drinkers with high levels of alcohol craving at the beginning of the experiment had more pronounced attentional, approach, and evaluative biases for alcohol cues, compared with those with low craving. There were also trends for the high craving group to show greater operant responding for beer reinforcement, but the latter findings were inconclusive, and no evidence was found of associations between the operant responding and cognitive bias measures. Conclusions: The finding of a relationship between subjective craving and cognitive biases for alcohol cues is consistent with incentive models of addiction. Methodological factors may have obscured the predicted relationships between cognitive bias and operant performance, such as the use of a specific reinforcer (beer) during the operant task, while a range of alcohol-related cues were used in the cognitive bias tasks.

INTRODUCTION

Repeated drug use appears to be associated with a range of cognitive biases, which favour the processing of drug-related cues, including biases in selective attention, evaluative judgements, and implicit approach tendencies. For example, studies using the visual probe task suggest that drug users selectively allocate their attention to drug-related cues at the expense of competing stimuli (for a review, see Field et al., 2005). In this task, pairs of stimuli are briefly presented on a computer screen and, on critical trials, each stimulus pair consists of a drug-related cue (e.g. a picture of a woman smoking a cigarette) and a matched control stimulus, which contains no drug-related content (e.g. a picture of a woman applying lipstick). Immediately after stimulus offset, a small visual probe appears in the location that had been occupied by one of the pictures, and participants are instructed to respond to the probe as rapidly as possible. Attentional biases for drug-related cues are reflected by faster response times to probes that replace drug-related pictures, rather than control pictures. Several studies using this task have indicated the presence of such biases in smokers (Ehrman et al., 2002; Bradley et al., 2003, 2004) and opiate addicts (Lubman et al., 2000).

Drug users also show biases in the explicit evaluation of drug-related stimuli, as well as in implicit approach tendencies to such stimuli. For example, smokers and alcoholics report elevated feelings of momentary pleasure when viewing smoking-related or alcohol-related scenes, respectively (Mucha et al., 1999, 2000), and smokers rate smoking-related pictures as more 'pleasant' than control images, whereas non-smokers do not show this pattern of evaluative bias (Mogg et al., 2003). Studies using implicit measures of approach biases indicate that hazardous drinkers tend to direct approach behaviours towards alcohol-related words (Palfai and Ostafin, 2003; Ostafin et al., 2003). One method of assessing the extent to which smoking-related pictures elicit approach responses in smokers is the 'stimulus–response compatibility' (SRC) task. In this task, smokers are required to categorize smoking-related and matched control pictures by moving a manikin figure either towards or away from the picture. We demonstrated that smokers were relatively faster than non-smokers at categorizing pictures when they had to make the manikin approach smoking-related pictures and avoid control pictures, compared with when they had to make the opposite response (i.e. avoid smoking pictures and approach control pictures; Mogg et al., 2003; Bradley et al., 2004). These findings suggest that smoking-related cues are more likely to elicit approach than avoidance behaviours in smokers, in comparison with non-smokers.

The observed cognitive biases for drug-related cues, such as attentional and approach biases, are consistent with the incentive-sensitization theory of addiction (Robinson and Berridge, 2003), and other theories of addiction based on incentive learning (Tomie, 1996; Franken, 2003). For example, according to the incentive-sensitization theory, addiction is a consequence of sensitization of drug-induced dopamine release in the nucleus accumbens, which leads to an elevation in the incentive value of the drug. Through a classical conditioning process, drug-associated environmental stimuli acquire conditioned incentive properties, or 'incentive salience', which causes them to appear attractive, grab attention, and elicit approach responses. Furthermore, according to the model, sensitization of the incentive value of drugs and associated stimuli is a continuous process that progresses with each exposure to drugs of abuse. Therefore, drugs and drug-related cues should acquire incentive motivational properties long before individuals are diagnosed with substance abuse problems. Indeed, research with non-dependent social drinkers indicates that the magnitude of attentional bias is positively associated with the amount of alcohol that is regularly consumed (Townshend and Duka, 2001; Jones et al., 2003; Field et al., 2004a).

The incentive-sensitization model also predicts that high levels of 'incentive salience' of drug-related cues should be...
associated not only with cognitive biases for those cues, but also with subjective drug craving (as assessed by questionnaires) and with behavioural indices of drug-seeking. There is evidence that subjective drug craving is associated with attentional bias for drug-related cues in cocaine addicts (Franken et al., 2000) and cigarette smokers (Mogg et al., 2003), as well as in recreational drug users such as cannabis users (Field et al., 2004b) and social drinkers (Field et al., 2004a). In addition, elevated craving in smokers seems to be associated with more positive explicit evaluations of smoking-related cues, and also with a greater implicit approach bias towards those cues (Mogg et al., 2003, 2005; Field et al., 2004c, 2005).

One aim of the present study was to extend our previous research (Field et al., 2004a) by examining the relationship between subjective craving for alcohol and multiple indices of cognitive bias for alcohol-related cues. In the present study, we measured attentional, explicit evaluation and implicit approach biases, as the latter was not included in our previous study. Another aim of the present study was to explore the relationships between the cognitive bias measures and a behavioural measure of drug-seeking, which was a progressive ratio operant task for alcohol (beer) reinforcers. This task has been used in previous studies as a measure of the motivation for drugs, including alcohol (Willner et al., 1998). In the task, participants make operant responses (e.g. button presses) for drug reinforcement (such as a small dose of alcohol) and the response requirement for each successive reinforcer progressively increases. Thus, the amount of effort that each participant expends to receive the drug can be said to be a behavioural measure of motivation for the drug, with the total number of responses made and the total number of reinforcers earned commonly used to infer the level of motivation. Performance on this task is sensitive to manipulations known to increase the motivation to drink alcohol, such as exposure to alcohol-related cues and negative mood (Willner et al., 1998). There is also evidence that negative mood (Willner and Jones, 1996) and cue exposure (Morgan et al., 1999) can increase operant responding for cigarette puff reward in smokers.

Thus, in the present study, participants completed measures of subjective alcohol craving before completing measures of attentional, approach, and evaluative biases for alcohol-related cues. To assess attentional bias, we used a visual probe task with alcohol-related pictures, which was similar to that used in a previous study in our laboratory (Field et al., 2004a). Pictures were presented for 500 and 2000 ms in order to explore the component processes of biases in visual orienting to alcohol-related cues: if attentional bias is evident for pictures presented for 500 ms, this is likely to represent a bias in the initial orienting of attention, whereas if attentional bias can be demonstrated for pictures presented for 2000 ms, then this is likely to represent a bias in the maintenance of attention, as multiple shifts of attention are possible within this time period (Bradley et al., 2003). To assess approach and evaluative biases for alcohol cues, we used modified versions of our SRC and picture valence rating tasks, which we have successfully used with smokers in our previous studies (Mogg et al., 2003). After completing these tasks, participants completed a progressive ratio operant task for alcohol reinforcement. Our primary hypothesis was that social drinkers with high levels of alcohol craving would have elevated attentional, approach, and evaluative biases for alcohol-related cues, relative to social drinkers with low levels of alcohol craving. Our secondary hypothesis was that individual differences in cognitive biases would be positively associated with the behavioural motivation for alcohol, that is, the number of responses made, or the number of reinforcers earned, on the progressive ratio operant task. As noted earlier, these hypotheses were primarily derived from Robinson and Berridge’s (2003) model of addiction, which proposes that conceptually distinct phenomena, such as self-reported craving (a subjective index of motivational state), the ability of drug cues to grab attention (as assessed with objective measures of cognitive processes), and behavioural measures of drug-seeking (such as operant performance for a drug reward) may be mediated by a common underlying mechanism, namely, the activation of a sensitized incentive-motivational state.

METHODS

Participants

Fifty students (17 male) from the University of Southampton took part in the study. Their mean age was 20.1 (SD = 2.0) years. In order to take part in the study, participants had to report drinking beer at least occasionally. Participants were not permitted to take part if they had ever received medical advice to give up or cut down alcohol consumption. All participants had normal or corrected to normal vision and spoke fluent English. The study was approved by the University of Southampton Psychology Research Ethics Committee.

Materials

The pictorial stimuli used in the visual probe task consisted of 14 colour photographs of alcohol-related scenes (e.g. man holding beer glass to mouth, bottles of spirits). Each was paired with a photograph of another scene matched as closely as possible for content but lacking any alcohol-related cues (e.g. man holding water bottle to mouth, mugs of tea). An additional 14 picture pairs (unrelated to alcohol) were prepared for use as practice and buffer stimuli in the computer tasks. The picture set was identical to that used by Field et al. (2004a). All pictures were 100 mm high × 125 mm wide, and they were digitized and converted to an indexed 256 colour palette. All tasks were presented on a Pentium II PC, with 15" VGA monitor, attached to a two button response box and standard keyboard.

Procedure

Participants were seated at a desk 1 m away from a computer monitor. After signing an informed consent form, participants provided a breath alcohol sample on a breathalyser (Lion Laboratories Ltd., Barry, UK). All participants had a breath alcohol level (BAL) of zero. Participants then completed the alcohol use questionnaire (AUQ; Mehrabian and Russell, 1978), the 14 item desires for alcohol questionnaire (DAQ; Love et al., 1998), and they provided information about the number of standard units of alcohol consumed in an average week, and the time elapsed since they last consumed an
alcoholic drink. Participants were also asked to rate ‘how strong your urge to drink alcohol is right now’ on an anchored scale, which ranged from 0 (not at all) to 10 (extremely) (Time 1).

Participants then completed the visual probe task. Each trial started with a central fixation cross shown for 500 ms, which was replaced by the display of a pair of pictures, side by side, for either 500 or 2000 ms. The distance between the inner edges of the pictures was 60 mm. Immediately after picture offset, a probe was presented in the position of one of the preceding pictures, until the participant made a response. The probe was a small arrow, which pointed either up or down. Participants were instructed to press one of two response buttons to indicate the identity of the probe. They were also instructed to look at the fixation cross at the start of each trial. There was an inter-trial interval of 1 s.

There were 10 practice trials, followed by 2 buffer trials and 168 trials in the main task (112 critical trials and 56 filler trials). During the critical trials, each of the 14 alcohol-related and control picture pairs was presented eight times, four times at each stimulus duration (500 and 2000 ms). Within each stimulus duration, each alcohol-related picture appeared twice on the left side of the screen, and twice on the right. The probe appeared in the location of either the alcohol-related or the control picture with equal frequency and there were an equal number of trials with each probe type. The 14 filler picture pairs were presented four times each (twice at each stimulus duration). Critical and filler trials were presented in a new random order for each participant.

After the visual probe task, participants re-rated their current level of urge to drink alcohol using the anchored rating scale (as described earlier) (Time 2). They then completed the picture rating and SRC tasks; the order of these tasks was counterbalanced across participants. The picture rating task consisted of two practice trials, in which filler pictures were presented, followed by 28 test trials in which each alcohol-related picture and control picture from the visual probe task was presented, one at a time, in a new random order for each participant. Each picture was presented for 2000 ms and, immediately after picture offset, a 7-point anchored rating scale was displayed on the screen until the participant’s response. The rating scale ranged from –3 (very unpleasant) to +3 (very pleasant), and participants were asked to press one of seven keys, which were correspondingly labelled from –3 to +3, to indicate how pleasant or unpleasant they found each picture. The inter-trial interval was 1000 ms. The visual probe and picture rating tasks were programmed in Inquisit version 1.33 software.

The SRC task consisted of two blocks, each of 128 trials. In each trial, a picture was displayed in the centre of the screen and a manikin figure was presented either above the picture or below the picture. The picture was either an alcohol-related or a control picture (which were those used in critical trials of the visual probe task). Each block of trials had a different stimulus–response assignment: in Assignment 1, participants were instructed to move the manikin towards the picture if it depicted an alcohol-related scene, and away from the picture if the scene was not alcohol-related. In Assignment 2, these stimulus–response relationships were reversed (i.e. participants were instructed to move the manikin away from alcohol-related pictures, and towards pictures that had no alcohol-related content). The order of Assignments 1 and 2 was counterbalanced across participants.

For each assignment, there were 16 practice trials, in which 8 alcohol-related and 8 control pictures were presented, followed by 112 test trials, with a short break after 56 trials. During the test trials, each of the 14 alcohol-related and 14 control pictures was presented four times. The manikin (a matchstick figure of a man), which was ~22 mm high × 15 mm wide, was presented 25 mm above or below the picture. The manikin appeared above the picture on 50% of trials, and below it on the other 50%. Participants responded by pressing the upper or lower buttons on a response box to move the manikin figure up or down the screen, respectively. The picture and manikin disappeared as soon as the manikin reached the edge of the screen or the picture. There was a 500 ms interval between trials. The latency was recorded between each picture onset and the response. Within each assignment block, the trials were presented in a new random order for each participant, so that picture type and manikin position varied over trials. The SRC task was programmed in C++.

Participants then completed a further DAQ and rating of urge to drink alcohol (Time 3) before completing the progressive ratio operant task with alcohol (beer) reinforcers. Participants were instructed to repeatedly press the space bar on the keyboard until they heard a high pitched tone, which was accompanied by the statement on the computer screen ‘please drink some beer now and then rate it for pleasantness’. Reinforcers, which were hidden from participants’ view and were handed to the participant by the experimenter whenever a reinforcement opportunity arose, were 25 ml of the participant’s choice of either lager (Fosters, 4% ABV) or bitter (John Smiths, 4% ABV), presented in clear plastic medicine cups. Immediately after consumption of each reinforcer, participants rated their degree of liking for the drink by marking a 7 point anchored scale, which ranged from –3 (strongly dislike) to +3 (strongly like), with 0 indicating ‘neutral’. Participants were instructed that they could terminate the task at any time by informing the experimenter that they did not wish to make any more responses. There was a minimum inter-response interval of 0.25 s, and successful responses were indicated by a low pitched tone. The response requirement doubled for each successive reinforcer, such that 4 responses were required for the first reinforcer, 8 for the second, 16 for the third, and so on, up to 2024 responses, which were required to gain access to the 10th reinforcer. The task terminated whenever participants indicated that they did not wish to make any more responses, or when they received the 10th reinforcer. The computer recorded the number of responses made and the number of reinforcers earned. The task was programmed in Inquisit version 1.33 software.

After the computer tasks, participants completed several self-report mood measures (e.g. anxiety, depression). For the sake of brevity the results of the mood measures are not reported in detail. Although the high craving group showed higher trait anxiety scores than the low craving group, exploratory correlations revealed no evidence of any significant relationships between the mood and cognitive bias measures. Further details are available on request from the first author. Finally, participants were debriefed and thanked for their time. Psychology students received course credit, and students from other departments received financial compensation (£5 sterling).
RESULTS

Group characteristics
In order to test our hypotheses, participants were allocated to either ‘low’ or ‘high’ craving groups based on a tertile split of overall scores on the DAQ that was completed at Time 1 (the beginning of the experiment). There were 17 participants (4 males, 13 females) in the low craving group, and 17 participants (5 males, 12 females) in the high craving group. The 16 remaining participants with moderate levels of alcohol craving were not included in the group comparisons. Table 1 shows summary data for low and high craving groups. All measures, apart from DAQ craving, were log transformed before analysis to reduce skewness. Independent samples t-tests were used to explore group differences in these variables. As can be seen in Table 1, groups differed significantly on all of the alcohol craving/urge measures throughout the experiment, but not in age, time elapsed since last alcoholic drink, units of alcohol consumed per week, or scores on the AUQ. Moreover, groups did not differ significantly in gender ratio, $\chi^2 = 0.70$, NS.

Visual probe task
Reaction time (RT) data from filler trials, and from trials with errors (1.7% of data), were discarded. To eliminate outliers, RTs were excluded if they were >2000 ms, and then if they were >2 SD above the mean (4.1% of data). Attentional bias scores were calculated by subtracting mean RTs to probes that replaced alcohol pictures from mean RTs to probes that replaced control pictures, such that positive attentional bias scores indicate vigilance for alcohol-related pictures. Attentional bias scores were analysed using a 2 × 2 ANOVA with group (low craving, high craving) as the between-subjects variable, and picture exposure duration (500/2000 ms) as the within-subjects variable. This revealed a significant main effect of group ($F(1, 32) = 5.04$, $P < 0.05$), but no other significant effects ($F < 1.49$, $P > 0.1$). Attentional bias scores were significantly larger in the high craving compared with the low craving group, as can be seen in Figure 1.

Table 1. Characteristics of high and low alcohol craving groups

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>t(32)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High craving (N = 17)</td>
<td>20.00</td>
<td>1.46</td>
<td>19.88</td>
<td>2.37</td>
<td>0.29</td>
<td>NS</td>
</tr>
<tr>
<td>Low craving (N = 17)</td>
<td>17.58</td>
<td>15.57</td>
<td>16.06</td>
<td>5.65</td>
<td>0.44</td>
<td>NS</td>
</tr>
<tr>
<td>Alcohol use questionnaire</td>
<td>53.53</td>
<td>34.09</td>
<td>53.91</td>
<td>22.52</td>
<td>0.49</td>
<td>NS</td>
</tr>
<tr>
<td>DAQ (Time 1)</td>
<td>3.30</td>
<td>0.43</td>
<td>1.69</td>
<td>0.33</td>
<td>12.16</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DAQ (Time 3)</td>
<td>3.43</td>
<td>0.72</td>
<td>1.81</td>
<td>0.56</td>
<td>7.32</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urge to drink (Time 1)</td>
<td>3.29</td>
<td>1.83</td>
<td>0.71</td>
<td>0.92</td>
<td>5.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urge to drink (Time 2)</td>
<td>4.00</td>
<td>1.62</td>
<td>1.06</td>
<td>1.30</td>
<td>6.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urge to drink (Time 3)</td>
<td>4.53</td>
<td>2.10</td>
<td>1.12</td>
<td>1.27</td>
<td>6.23</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Units per week, self-reported units of alcohol consumed per week; time since last drink, self-reported time elapsed since last alcoholic drink in hours; DAQ, mean scores on the desires for alcohol questionnaire, possible range of scores 1–7 (low craving–high craving); Urge to drink alcohol, possible range of scores is 0–10 (low craving–high craving).

Picture rating task
Mean pleasantness ratings for the alcohol and control pictures were +1.64 (SD = 0.68) and +1.40 (SD = 0.57), respectively, in the high craving group, and +1.37 (SD = 0.57) and +1.83 (SD = 0.50), respectively, in the low craving group. ‘Evaluative bias scores’ were calculated by subtracting mean pleasantness ratings for control pictures from those for alcohol pictures, such that higher bias scores indicate a relative preference for alcohol over control pictures. The high craving group had significantly higher evaluative bias scores than the low craving group (+0.25, vs -0.45, $t(32) = 2.33$, $P < 0.05$).

SRC task
RT data from trials with errors (2.8% of data) were discarded. To eliminate outliers, RTs were excluded if they were >2000 ms, and then if they were >2 SD above the mean (5.0% of data). We computed a mean RT for each assignment (1, approach alcohol and avoid control vs 2, avoid alcohol and approach control). These data were analysed using a 2 × 2 ANOVA, with group (high craving, low craving) as the between-subjects variable, and assignment type as the within-subjects variable. The main effect of group was not significant ($F(1, 32) = 0.09$, $P > 0.1$), but there was a significant main effect of assignment type ($F(1, 32) = 8.39$, $P < 0.01$), which was subsumed under a significant group × assignment type interaction ($F(1, 32) = 5.68$, $P < 0.05$). In order to explore the interaction, paired samples t-tests were used to compare RTs during the different assignments, separately for each group. As can be seen in Figure 2, the high craving group compare RTs were significantly faster to approach rather than avoid alcohol-related pictures ($t(16) = 4.26$, $P < 0.01$), but there was no significant difference in the low craving group ($t(16) = 0.33$, $P > 0.1$).

Progressive ratio operant task
The high and low craving groups were compared on two measures of operant performance: (i) the number of operant responses made (which was log transformed before analysis...
to reduce skewness) and (ii) the number of reinforcers earned. There were trends that approached significance for the high craving group to make more responses than the low craving group (untransformed means were 469 responses in the high craving group vs 193 in the low craving group \( t(32) = 1.89, \ P < 0.07 \), and for the high craving group to earn more reinforcers than the low craving group \( 5.76 \text{ vs } 4.71; \ t(32) = 1.92, \ P = 0.06 \)).

The groups were also compared on their ratings of reinforcer liking, which were averaged for each individual across all reinforcers. The high craving group gave significantly higher ratings of reinforcer liking than the low craving group \(+1.74 \text{ vs } +1.07; \ t(32) = 2.04, \ P = 0.05 \).

**Correlations**

Pearson correlations were calculated to evaluate the predicted relationships between the subjective craving, cognitive bias, and operant performance measures while using data from the whole sample \( (N = 50) \), and also to examine the extent to which these measures and their predicted inter-relationships were associated with alcohol consumption (e.g. weekly alcohol intake, time since last alcoholic drink). Variables analysed were attentional bias scores (averaged across 500 and 2000 ms conditions), approach bias scores (RTs during the avoid-alcohol assignment minus RTs during the approach-alcohol assignment, such that positive scores indicate a tendency to approach alcohol cues), evaluative bias scores from the pleasantness rating task (described earlier), subjective alcohol craving (DAQ scores at Time 1), weekly alcohol consumption (number of units consumed in an average week), AUQ scores, time elapsed since last alcoholic drink, operant responding (number of responses made and reinforcers earned), and reinforcer liking. Weekly alcohol consumption, AUQ scores, time elapsed since last alcoholic drink, and the number of responses made in the operant task were log transformed before analysis to reduce skewness.

There were significant positive correlations between attentional bias and evaluative bias \( r = 0.31, \ P < 0.05 \), and between approach bias and evaluative bias \( r = 0.32, \ P < 0.05 \). Initial craving (DAQ at Time 1) was significantly correlated with attentional \( r = 0.39, \ P < 0.01 \), approach \( r = 0.33, \ P < 0.05 \), and evaluative \( r = 0.43, \ P < 0.05 \) biases for alcohol cues. There was a trend, which approached significance, for a negative correlation between time elapsed since last alcoholic drink and attentional bias \( r = -0.27, \ P < 0.06 \). However, a partial correlation revealed that the positive correlation between craving (DAQ at Time 1) and attentional bias remained significant, even when controlling for the effect of time elapsed since last drink \( r = 0.38, \ P < 0.01 \).

With regard to the measures from the operant task, the number of responses made, number of reinforcers earned, and reinforcer liking were all significantly inter-correlated \( r > 0.32, \ P < 0.05 \). There was also a significant positive correlation between evaluative bias and reinforcer liking \( r = 0.30, \ P < 0.05 \), and there was a trend that approached significance for a positive correlation between approach bias and reinforcer liking \( r = 0.27, \ P < 0.06 \). Initial craving was also significantly positively correlated with reinforcer liking during the operant task \( r = 0.37, \ P < 0.01 \). However, there were no significant correlations between measures of operant performance (responses made or reinforcers earned) and measures of cognitive biases for alcohol cues (i.e. attentional, approach, or evaluative bias) or subjective alcohol craving \( r < 0.15, \ P > 0.1 \).

Weekly alcohol consumption and AUQ scores were significantly positively correlated with each other \( r = 0.73, \ P < 0.01 \), but neither variable was significantly correlated with any of the craving, cognitive bias, or operant performance measures \( P > 0.1 \).

**DISCUSSION**

Results from the present study indicate that subjective alcohol craving is associated with cognitive biases for alcohol-related cues in social drinkers. Social drinkers with high levels of alcohol craving had more pronounced attentional, approach, and evaluative biases for alcohol-related cues, relative to those with low levels of alcohol craving. However, individual differences in cognitive bias measures and subjective craving were not associated with individual variation in behavioural motivation for alcohol, as assessed by a progressive ratio operant task with beer reinforcers. The implications of these results for theories of craving and drug use will be discussed.

The present results not only replicate our previous finding that alcohol craving was correlated with a greater attentional bias for alcohol cues in social drinkers (Field et al., 2004a), but also reveal corresponding associations between alcohol craving and other cognitive bias indices: namely, an explicit evaluative bias and an implicit approach bias for alcohol-related cues. These findings are also consistent with previous studies showing that subjective craving is associated with enhanced attentional biases for drug-related cues in other samples of drug users, including cannabis users and cigarette smokers (for reviews see Franken, 2003; Field et al., 2005), as well as with studies showing associations between subjective hunger and attentional bias for food-related stimuli (Mogg et al., 1998).

The present results seem consistent with Robinson and Berridge’s (2003) model, in that they demonstrate a...
relationship between subjective drug craving and cognitive indices of the ‘incentive salience’ of drug-related cues, such as increased allocation of attention towards those cues. According to Franken (2003), high levels of craving can be both a cause of, and a consequence of, an elevation in attentional biases for drug-related cues: high levels of craving may cause a search of the environment for drug-related cues, but prolonged processing of drug-related cues may cause further increases in subjective craving. The present results do not permit an analysis of any causal relationship between craving and biassed cognitive processing of alcohol cues. Previous research with smokers suggests that manipulations designed to increase the motivation to smoke, such as a period of nicotine deprivation, or ingestion of alcohol, can increase attentional and evaluative biases for smoking-related cues (Field et al., 2004c, 2005), which seems compatible with the proposal that a common incentive-salience mechanism may elicit both subjective craving and selective processing of drug cues (Robinson and Berridge, 2003). Future studies may wish to extend this research by examining whether manipulations known to increase the motivation to drink alcohol, such as induction of negative mood or exposure to alcohol cues (Willner et al., 1998), produce increases in cognitive biases for alcohol cues in social drinkers.

Following the theories discussed above (Robinson and Berridge, 2003; Franken, 2003), we had also hypothesized that individual differences in the incentive value of alcohol and alcohol-related cues (as reflected by indices of subjective craving and cognitive biases) should be directly associated with indices of drug-seeking behaviour (as reflected by performance on the progressive ratio operant task). There were notable trends, which were consistent with this prediction and which approached significance, for the high craving group to make more operant responses for alcohol reinforcers, and also to earn more reinforcers, than the low craving group. No significant correlations were found between operant responding, and subjective craving or cognitive biases for alcohol cues, although the strength of operant behaviour was positively associated with subjective liking of the reinforcer (beer). Thus, while the relationship between operant responding and craving was inconclusive, the present results suggest that the degree of subjective liking of the reinforcer used in this study (i.e. beer) was predictive of operant responding. Previous studies using progressive ratio operant tasks have demonstrated associations between subjective craving and the level of operant responding for drug reinforcers in both cigarette smokers (Willner et al., 1995; Morgan et al., 1999) and alcohol users (Willner et al., 1998).

This mixed pattern of findings highlights various conceptual and methodological issues, which may be useful to consider further in future research into predictors of drug-seeking behaviour. First, the incentive-sensitization model of addiction (Robinson and Berridge, 2003) suggests that it is helpful to distinguish the unconditioned hedonic properties of drugs of abuse (drug ‘liking’), from drug ‘wanting’, as there are conditions under which they can be dissociated. This model also suggests that drug-wanting (reflected by subjective craving) should be a better predictor of overt drug-seeking behaviour (operant performance) than drug-liking, as drug-wanting is mediated by incentive sensitization mechanisms. A second issue, which also seems important in interpreting the findings across studies, concerns the specificity of the various measures of operant responding, reinforcer liking, craving and cognitive biases. In the present study, the operant responding and subjective liking measures related to the specific reinforcer (beer), whereas the craving and cognitive bias measures related to alcohol and alcohol cues in general. Operant responding for a particular reinforcer may be better predicted by reinforcer-specific measures of craving and cognitive biases, rather than by the more general alcohol-related measures of craving and cognitive biases used here (i.e. operant responding for beer reinforcers may be better predicted by measures of subjective craving for beer and cognitive biases for beer cues).

There are some limitations of the methodology employed in the present study, which could be addressed in future studies of this type. First, tasks were completed in a fixed order, so all participants completed the operant task immediately after the cognitive bias measures. Future studies may wish to present the cognitive bias and operant tasks in a counterbalanced order, in order to control and assess potential order effects (e.g. fatigue). Second, the majority of the participants in the present study were female. Given evidence indicating gender differences in the factors that influence alcohol consumption (Walitzer and Sher, 1996), we suggest that researchers should be cautious before generalizing the present results to male populations.

In summary, the present results indicate that elevated alcohol craving in social drinkers is associated with increased biases for alcohol cues in various aspects of cognitive functioning, including selective attention, implicit approach tendencies, and explicit evaluative judgements. Such biases are consistent with expectation from incentive models of addiction and drug use. The results also showed trends for the high craving group to show greater operant responding for an alcohol reinforcer (i.e. beer). Although the latter findings were inconclusive, they highlight various methodological and conceptual issues, which should be taken into account in future studies that investigate the relationship between operant drug-seeking behaviour, subjective craving, and cognitive biases for drug cues.

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