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Effects of a low dose of alcohol on cognitive biases and craving in heavy drinkers

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Abstract

Rationale—Heavy alcohol drinking increases the incentive salience of alcohol-related cues. This leads to increased appetitive motivation to drink alcohol as measured by subjective craving and cognitive biases such as attentional bias and approach bias. Although these measures relate to the same construct, correlations between these variables are often very low. Alcohol consumption might not only increase different aspects of appetitive motivation, but also correlations between those aspects.

Objectives—To investigate the effect of a low alcohol dose on changes in various measures of appetitive motivation.

Materials and methods—Twenty-three heavy social drinkers were tested in 2 sessions, once after receiving an alcohol prime dose and once after receiving a placebo drink. After drink administration, attentional bias was measured with a visual-probe task using concurrent eye movement monitoring. Furthermore, we measured the approach bias with a stimulus response compatibility task and subjective craving with the Desires for Alcohol Questionnaire.

Results—After the alcohol prime dose, participants had higher levels of craving and more pronounced attentional bias (faster reaction times to probes that replaced alcohol rather than control pictures, increased maintenance of gaze on alcohol pictures, and a higher percentage of first eye movements directed toward alcohol pictures). Approach bias was not influenced by the alcohol prime dose. The correlation between attentional bias and approach bias was significantly higher after the alcohol than after the placebo drink.

Conclusions—A low alcohol dose increased most measures of appetitive motivation for alcohol and increased the interrelation between cognitive measures of this construct.

Keywords

Attentional bias; Approach bias; Eye movements; Craving; Alcohol prime dose

According to the incentive sensitization theory (Robinson and Berridge 1993), after a substantive period of heavy alcohol drinking, cues related to drinking (e.g., beer glasses, wine bottles, a pub) become associated with the effects of alcohol by a conditioning process. During this process, these cues acquire similar appetitive motivational characteristics as alcohol. As a consequence, they become more salient and receive a disproportionate amount of attention (attentional bias). Once attention is focused on the cues, other conditioned appetitive motivational responses are triggered, such as craving for the drug and a tendency to have a dominant approach response toward alcohol-related cues, i.e., approach bias. Only heavy drinkers and not light drinkers have been found to show attentional bias (e.g. Townshend and Duka 2001) and approach bias (Field et al. 2007b). In this study, we examine the effect of a low alcohol dose on measures of appetitive motivation to use alcohol.

Whereas subjective craving is measured with self-report questionnaires, cognitive biases such as attentional bias and approach bias are measured with reaction time tasks that reflect relatively automatic and uncontrolled processes. A measure of attentional bias is the visual-probe task, which assesses the allocation of visuospatial attention. In this task, two stimuli representing two categories (e.g., alcohol and neutral) are presented simultaneously on a computer screen. After a short interval, the stimuli disappear and a probe (e.g., an arrow) replaces one of the stimuli. Participants respond as quickly as possible to the probe (i.e., identifying the arrow as pointing up or down) by pushing a button. Faster responses to probes replacing alcohol stimuli indicate attentional bias toward alcohol relative to neutral stimuli. Heavy social drinkers typically show attentional bias on longer (500-2,000 ms), but not on short (200 ms) stimulus durations (Townshend and Duka 2001; Field et al. 2004b). By contrast, inpatient alcoholics showed attentional bias with a short stimulus duration (50 ms; Noel et al. 2006), but not with longer stimulus durations (Noel et al. 2006; Townshend and Duka 2007). These findings might be explained as follows. The incentive value of alcohol cues motivates heavy drinkers to maintain their attention on these cues. Ultimately, in alcoholics, the salience of these cues has become high enough to trigger attention automatically, reflected by early engagement of attention toward alcohol cues. The absence of a maintenance bias in alcoholics in treatment might be caused by a strategic attempt to distract their attention from alcohol cues (Stormark et al. 1997).

Monitoring of eye movements during a visual-probe task sheds further light on the attention process. We will measure eye movements during the visual-probe task because this offers an unambiguous measure of attention compared to the measurement of response latencies. Response latencies only provide an indirect measure of attention and they only inform about the allocation of attention at the time of stimulus offset. In contrast, eye movements are direct manifestations of attention, and the monitoring of eye movements offers the possibility of assessing attention during the entire length of stimulus presentation. Attentional bias in eye movements, e.g., prolonged maintenance of gaze ('dwell time') or a higher proportion of initial eye movements directed toward substance-related vs neutral cues, has been demonstrated in tobacco smokers and cannabis users (Mogg et al. 2003; Field et al. 2004a, 2006). However, to date, no investigators have explored attentional bias in eye movements to alcohol-related cues among heavy drinkers.

Approach bias can be measured with the stimulus response compatibility task (SRC; De Houwer et al. 2001; Mogg et al. 2003). In the 'alcohol' version of this task, alcohol-related or neutral pictures appear one by one on a computer screen. Together with these pictures, a manikin is presented. In one block of the SRC task, participants have to move the manikin toward alcohol-related pictures and away from neutral control pictures, thereby measuring approach tendencies. In a second block, this is reversed, thereby measuring avoidance tendencies. The difference in response latencies between the two blocks permits the

inference of 'approach bias': if participants are faster in the approach than the avoidance block. In a recent study in which the SRC task was used (Field et al. 2007b), only heavy drinkers, but not light drinkers, were significantly faster to approach rather than avoid alcohol-related pictures. Likewise, tobacco smokers were faster to approach rather than avoid smoking-related pictures in the SRC task (Mogg et al. 2003; Bradley et al. 2004).

A low dose of alcohol has been shown to increase subjective craving for alcohol (De Wit and Chutuape 1993; Chutuape et al. 1994; Kirk and de Wit 2000) and attentional bias (indicated by faster reaction times to probes that replace alcohol-related rather than control pictures; Duka and Townshend 2004). There is no evidence yet for the effects of an alcohol priming dose on approach bias, although because it also measures appetitive motivation for alcohol use, we expect approach bias to increase after a low alcohol dose. There are numerous explanations for these hypothesized effects, one of which we focus on in this article. Acute alcohol administration has been found to impair inhibitory control (Fillmore and Vogel Sprott 1999, 2000, 2006; Fillmore et al. 1999). When sober, people may use cognitive resources to inhibit automatic responding to the incentive motivational properties of alcohol cues. During alcohol intoxication, however, weakening of inhibitory control might increase automatic responding to the incentive motivational properties of alcohol cues. This leads to the prediction that a priming dose of alcohol should increase the magnitude of attentional bias (as indexed with reaction time measures and eye movements) and approach bias (on the SRC task) for alcohol-related cues.

In line with the incentive sensitization theory (Robinson and Berridge 1993), craving, attentional bias, and approach bias have been theorized to be part of the same general underlying construct, namely, appetitive motivation to use alcohol (Wiers et al. 2007). However, there is mixed evidence for the interrelation and cooccurrence of the constructs. As for the approach bias, researchers using the SRC and visual-probe task did not find correlations between the approach bias and attentional bias for alcohol cues in heavy drinkers (Field et al. 2005b, 2007a), but did so for smoking cues in smokers (Mogg et al. 2005). Subjective craving has been found to correlate with both attentional bias and approach bias for alcohol cues in a number of studies by Field et al. (2004b, 2005b, 2007a, b) and with gaze dwell time for smoking cues (Mogg et al. 2005). Using different paradigms, Van den Wildenberg et al. (2006) did find a correlation between approach associations (measured with the implicit association task) and attentional bias (measured with an alcohol Stroop task) in heavy drinkers. They also found a trend in correlation between craving during the ascending limb of the blood alcohol curve and approach associations before alcohol intake.

Other evidence from studies reporting craving and attentional bias is not conclusive about their relation; many studies found positive correlations (e.g., Sayette et al. 1994; Franken et al. 2000a, b), others report no significant correlations (e.g., Ehrman et al. 2002). Field et al. (2004b) tested correlations between different aspects of attentional bias (measured with a visual-probe task) and craving. In that study, craving was correlated with the maintenance of attention (measured by presenting the stimuli for a relatively long duration=2,000 ms), but not with earlier attention processes, such as a rapid shifting of attention to alcohol-related cues (inferred from reaction times when stimuli were presented for 500 and 200 ms). Franken (2003) suggests a bidirectional causal relation between attentional bias and craving. Two studies reported that an experimental increase in attentional bias led to increased subjective craving (Field and Eastwood 2005; Field et al. 2007a) and drinking (Field and Eastwood 2005). However, an experimental decrease in attentional bias has not been found to decrease craving or drinking behavior (Field et al. 2007a; Schoenmakers et al. 2007). In sum, there is ample evidence for the interrelation of attentional bias, approach bias, and craving, but it is not clear under which conditions these relations are manifested.

We hypothesize that, relative to a placebo, an alcohol priming dose will increase the magnitude of subjective craving, attentional bias, and approach bias. Furthermore, we hypothesize that the alcohol priming dose will increase the strength of the correlations between measures of craving, attentional bias, and approach bias because alcohol will diminish the inhibitory control over performance on these tasks. Performance on reaction time measures is not a purely automatic process, but is partly influenced by inhibitory and attentional control (e.g., Payne 2005). The type and amount of control that can be exerted likely varies between tasks that require different ways of responding. This may often account for low correlations between different tasks of the same construct. However, when inhibitory control is diminished, performance on these measures should be less determined by control over performance and relatively more by automatic, uncontrolled processes. As a consequence, performance on these tasks will be less determined by construct-‘irrelevant’ variance, leading to increased construct validity. When the underlying construct of different tasks is the same, performance on these tasks will correlate better. Thus, after an alcohol prime dose, we expect an increase in the correlation between subjective craving, attentional bias, and approach bias because they are all thought to be outputs of the same underlying process, i.e., appetitive motivation for alcohol.

Altogether, the present study investigates the effect of a small alcohol dose in heavy drinkers on attentional bias, approach bias, and self-reported craving, and correlations between these constructs. We hypothesize that after an alcohol prime dose, the appetitive motivational system will be sensitized, thereby increasing attentional bias, approach bias, and craving. We also test whether the correlations between these measures of appetitive motivation increase after the ingestion of the alcohol prime dose.

Materials and methods

Participants

Participants were 23 students (12 males, 11 females) from the University of Liverpool. Their mean age was 20.3 years (standard deviation [SD]=2.2). They were invited to take part if they self-reported consuming more than 21 (males) or 14 (females) units of alcohol per week. These levels were chosen as they reflect drinking alcohol at levels above those deemed safe by the UK Department of Health (see Edwards 1996). Weekly alcohol consumption was verified with a self-report questionnaire based on the time-line follow-back procedure (Sobell and Sobell 1990). On average, male participants drank 43.6 U/week (SD=13.51; range 23-62.5), while females drank 27.2 U/week (SD=15.75; range 16-68). On the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al. 1993), male participants scored an average of 15.6 (SD=5.48; range 8-25), while females scored an average of 13.9 (SD=5.47; range 8-27). The range of AUDIT scores indicates that all participants met the criteria for hazardous drinking (AUDIT score of 8 or above; Babor et al. 2001). The experiment received ethical approval from the University of Liverpool Committee on Research Ethics.

Materials

The visual-probe and SRC tasks were similar to those used previously, and used the same picture set as in previous studies (Field et al. 2004b, 2005b). This set consisted of 14 pairs of alcohol and matched neutral photographs. Alcohol-related pictures depicted alcohol-related scenes (e.g., a close-up of a female model drinking wine), and each was paired with a control photograph that was matched as closely as possible on perceptual characteristics (e.g., complexity, brightness), but which lacked any alcohol-related content. Another 10 pairs of pictures (not alcohol-related) were selected for practice and buffer trials within the tasks. All pictures were 100 mm high×125 mm wide. The tasks were programmed in

Inquisit version 1.33 and presented on a pentium PC with 17" VGA monitor attached to a standard keyboard. Horizontal eye movements were recorded during the visual-probe task using an infrared head-mounted Eyetrace 300x system (Applied Science Laboratories, Bedford, MA, USA).

Procedure

Testing took place in a quiet laboratory inside the School of Psychology at the University of Liverpool campus. All participants were tested between noon and 6 P.M. They were tested twice with exactly 1 week between the testing sessions. On one testing day, participants received an alcoholic drink; on the other day, a placebo drink. The order of the drinks was counterbalanced between participants.

Participants were asked to refrain from drinking more than three alcoholic drinks the night before each session, not to drink coffee or tea 2 h before each session, and to have a light meal 1 to 2 h before each session. At the start of the first session, participants gave their informed consent before being weighed and were then breathalyzed using a Lion Alcolmeter 500 (Lion Laboratories, Barry, UK). All participants had a breath alcohol level (BAL) of 0 at the start of both sessions. Participants then completed questionnaires about their alcohol use and alcohol-related problems (time-line follow-back; Sobell and Sobell 1990) and AUDIT (Saunders et al. 1993). The remainder of the procedure was identical for both testing days.

At time 1, participants completed the 14-item version of the Desires for Alcohol Questionnaire (DAQ; Love et al. 1998) and subjective intoxication scales (SIS; Duka et al. 1998). These were 100 mm visual analog scales (VAS), which required the participants to rate how they felt 'right now' in response to the terms 'lightheaded', 'irritable', 'stimulated', 'alert', 'relaxed', and 'contented'. Participants were then administered either the alcohol or placebo drink. All drinks were prepared by a second experimenter and were administered double blind. The alcohol prime dose consisted of a mix of one part vodka mixed with three parts tonic water and a few drops of Tabasco sauce. All participants received a dose of 0.3 g/kg alcohol up to a maximum of 100 ml of vodka. The placebo drink consisted of tonic water only in the same volume as the alcohol mix. A few drops of vodka were smeared on the rim of the glass for each drink. Participants were given 5 min to consume the drink before they rated the strength of the taste of the drink on a Likert scale ranging from 1 ("very weak") to 4 ("very strong") (Field and Duka 2002). Participants were then allowed to read magazines for 10 min to allow sufficient time for the alcohol to be absorbed.

At time 2 (10 min after the participants had finished the drink), participants filled out the DAQ and SIS after which the second experimenter came in to measure the participants' BAL. Neither the first experimenter nor the participant was told the outcome of this measure. The participants then performed the visual-probe task with concurrent eye movement monitoring. Participants were seated 1 m from a computer monitor while wearing eye movement recording goggles and resting on a chin rest. To calibrate the eye monitoring equipment, they were instructed to look at a fixation cross in the center of the screen for 10 s. During the last 5 s of this period, their horizontal eye movements were recorded.

Each trial of the visual-probe task started with a central fixation cross for 1,000 ms. Then a picture pair was presented for 2,000 ms, one picture on the left side and one on the right side of the screen, their inner edges 60 mm apart. Immediately after picture offset, a probe (an arrow that pointed up or down) appeared in the location that had been occupied by one of the pictures. Before the task, participants were instructed to look at the fixation cross on each trial. As soon as the arrow would appear they had to respond as quickly as possible while trying to avoid making mistakes. Participants responded to the probe by pressing the

corresponding arrow on the keyboard. After each response there was an intertrial interval of 500 ms.

The visual-probe task commenced with 10 practice trials consisting of practice pictures only. Instructions were then clarified before the main task, which consisted of 2 buffer trials in which the practice picture pairs were again presented, followed by 56 critical trials. All 14 alcohol-control picture pairs were presented four times in the critical trials. Each alcohol picture and control picture appeared twice on the left and twice on the right side of the screen. Congruent trials (with probes replacing alcohol pictures) and incongruent trials (with probes replacing control pictures) occurred with equal frequency and there were an equal number of probes of each type. The latency and accuracy of participants' responses were recorded. Trials were presented in a new random order for each participant on each testing day.

After completing the visual-probe task, participants removed the eye goggles before completing the SRC task. Each trial of the SRC task started with a blank screen for 1,000 ms. Then an alcohol or control picture was presented in the center of the screen and a small manikin was presented either directly above or below the picture. Participants had to move the manikin either toward or away from the picture by using the arrow keys (up and down) on the keyboard. After a correct response, the manikin moved toward or away from the picture and then the screen was cleared. If participants made an incorrect response, a large red 'X' appeared in the center of the screen before the screen was cleared. There was an intertrial interval of 500 ms.

Participants were instructed to categorize pictures appearing on the screen as either alcohol-related or unrelated to alcohol by moving the manikin. They were further instructed to respond as quickly as possible without making mistakes. The SRC task consisted of two blocks. In the 'approach alcohol' block, participants had to move the manikin toward the alcohol pictures and away from the nonalcohol-related pictures. In the 'avoid alcohol' block, these instructions were reversed. Each block commenced with eight practice trials consisting of four alcohol-related and four control pictures. Instructions were then clarified before the main part of a block, consisting of 56 critical trials. During the critical trials, 14 alcohol and 14 control pictures were presented four times each: twice with the manikin above each picture and twice below. The latency and accuracy of the participants' responses were recorded. Trials were presented in a new random order for each participant on each testing day. The order of presentation of 'approach alcohol' and 'avoid alcohol' blocks was counterbalanced across participants, and block order remained the same across the two testing sessions.

Upon completion of these tasks, the participants once again filled out the DAQ and SIS (time 3). The participants were then asked to estimate how many standard 25 ml 'shots' of vodka had been in their drink (0, 1, 2, 3, 4, or more) before being breathalyzed by the second experimenter again. Before being discharged, the participants were advised to remain in the laboratory until their BAL had dropped down to 0, and they were advised not to drive, ride a bike, or operate any kind of machinery for the remainder of the day. During the second testing session, the above procedure was repeated with the exception that the participants received a different drink (alcohol or placebo). Before being discharged, the participants were fully debriefed and given £20 UK sterling as compensation for their time and expenses.

Data analyses

Eye movements

Eye movement data were analyzed using the Orbit Eye-Trace software (IOTA AB, Sweden). Eye movements during the visual-probe task were measured to the regions of the screen that corresponded to those occupied by alcohol and control pictures, and the center region. The position of gaze was measured every 8.3 ms (120 Hz) during the 2,000 ms stimulus presentation in each trial. For each trial, we calculated the total time (in ms) in which gaze was directed at one of the three regions, which permitted us to calculate gaze 'dwell time' on alcohol-related and control pictures. The first eye movement was defined as the first fixation of at least 100 ms duration in the region of either the alcohol or control picture, at least 100 ms after picture onset and before picture offset. This permitted us to calculate the percentage of initial eye movements that were directed at alcohol-related vs control pictures during the task. Due to a technical failure, we lost information about the position of alcohol and control pictures for one participant. Therefore, we could not interpret her eye movement data and visual-probe reaction time data.

Data distribution

Outlying reaction time (RT) data from the SRC task were removed when they were more than 2,000 ms or less than 200 ms, and when they were more than 3 SDs above the mean for each participant. Visual-probe RT data were positively skewed; to reduce the effect of outlying data points, median reaction times were calculated for congruent and incongruent trials. All dependent variables were then checked for normality. Responses on the subjective intoxication scales in both sessions and mean gaze 'dwell time' for alcohol pictures were not normally distributed and could not be transformed to normality using log or square root transformations. Therefore, nonparametric tests were used to analyze these variables.

Session order

Session order (alcohol first, then placebo, or vice versa) was counterbalanced between participants. To check whether effects differed between each order, we used session order as a between-subjects variable in our analyses of the DAQ, visual-probe RT, and SRC task. Session order did not contribute significantly to any of these analyses. For the other dependent variables, scores for each session order group were compared: nonparametric Mann-Whitney tests for gaze dwell time and the difference scores from time 1 to time 2 for SIS; independent samples *t* tests on first eye movement, 'taste of drinks', and 'alcohol content'. None of these tests were significant. Session order was therefore excluded from all further analyses.

Results

Manipulation checks

Subjective intoxication scales—We performed nonparametric Wilcoxon signed-rank tests to compare differences within sessions (from time 1 to time 2) and across sessions for VAS ratings of 'lightheaded', 'irritable', 'stimulated', 'alert', 'relaxed', and 'contented'. In both sessions, light-headedness increased after drink administration (i.e., from time 1 to time 2), but lightheadedness at time 2 in the alcohol session was higher than in the placebo session, $z=3.18$, $p<0.01$. Alertness decreased significantly in the alcohol session after the drink (see Table 1 for more details).

Taste of drinks and perceived alcohol content—To check whether the participants were aware of the difference between the alcohol and placebo drink, we performed paired-

samples t tests on perceived strength of the drinks and perceived number of vodka shots in the drinks. They perceived the alcoholic drink to be significantly stronger and to contain more vodka shots than the placebo drink, $t(22)=4.41$, $p<0.01$, $t(22)=4.41$, $p<0.01$, respectively.

Breath alcohol level—The BAL for all participants was 0 mg% at time 1 in both sessions and at time 2 in the placebo session. In the alcohol session at time 2, the average BAL was 0.40 mg% (SD=0.23) and declined to 0.30 mg% (SD=0.13) at time 3.

Craving (Desires for Alcohol Questionnaire)

We compared the differences in the mean DAQ scores with repeated-measures ANOVA with time (time 1, time 2) and session (alcohol, placebo) as within-subjects variables. The interaction time $\times$ session was significant, $F(1,22)=6.39$, $p=0.02$. Post hoc tests revealed a significant increase in DAQ scores during the alcohol session from time 1 to time 2, $t(22)=2.64$, $p=0.03$. There was, however, no such increase in the placebo session, $t(22)=1.09$, $p=0.58$ (see Table 2).

Visual-probe task reaction times

Because of technical problems, we lost visual-probe reaction time data from one participant. Due to errors, 1.5% of the data was removed. We performed repeated-measures ANOVA with trial type (congruent, incongruent) and prime session (alcohol, placebo) as within-subjects variables. The two-way interaction was significant, $F(1,21)=5.85$, $p=0.03$. Paired samples t tests revealed a significantly faster reaction time for congruent than incongruent trials in the alcohol session, $t(21)=2.20$, $p=0.04$, indicating an attentional bias. In the placebo session, there was no such effect, $t(21)=0.20$, $p=0.85$ (see Table 2).

Gaze dwell time

Data were not normally distributed and data could not be transformed to normality. We performed nonparametric Wilcoxon signed-rank tests to compare the differences between mean gaze ‘dwell time’ on alcohol and control pictures during trials of the visual-probe task in each session. In the alcohol session, dwell time on alcohol pictures was significantly longer than dwell time on control pictures, $z=2.32$, $p=0.02$. In the placebo session, there was no difference between alcohol and control pictures, $z=1.08$, $p=0.28$ (see Table 2).

Direction of first eye movement

To examine whether participants showed a bias in the first eye movement direction during the visual-probe task, the percentage of first eye movements toward alcohol pictures was compared with 50% (which indicates no bias). After the alcohol prime dose, this percentage was significantly greater than 50%, $t(21)=2.12$, $p=0.05$. After the placebo prime dose, the percentage did not differ significantly from 50%, $t(21)=-0.43$, $p=0.68$ (see Table 2). Also, a dependent t test revealed that the first eye movement percentages toward alcohol pictures significantly differed between prime sessions, $t(21)=2.15$, $p=0.04$.

SRC task

Due to errors, 3.4% of data was excluded, and a further 2.7% was also excluded due to outliers. Data from two participants were excluded because they had an outlying high error rate, and data from one further participant were excluded due to outlying mean reaction times in the avoid alcohol block. Data were analyzed using a $2\times 2\times 2$ mixed design repeated-measures ANOVA with SRC block (‘approach alcohol’, ‘avoid alcohol’) and prime session (alcohol, placebo) as within-subjects factors and order of block (first block: ‘approach alcohol’, first block: ‘avoid alcohol’) as between-subjects factor. This three-way interaction

was not significant $F(1,18)=1.05$, $p=0.32$. The hypothesized interaction of session $\times$ SRC block was not significant either, $F(1,18)=2.62$, $p=0.12$ (see Table 2). There was a significant main effect of SRC block, $F(1,18)=7.63$, $p=0.01$, as participants were significantly faster during the 'approach alcohol' block compared to the 'avoid alcohol' block, indicating an approach bias in both sessions.

Correlations between dependent variables

To test whether correlations between measures of appetitive motivation increase after ingestion of the alcohol prime dose, we compared the strength of correlations in the alcohol session with those in the placebo session. First, we computed the five relevant variables; attentional bias RT was calculated by subtracting the mean reaction times on congruent trials from incongruent trials separately for each session. Mean gaze 'dwell time' bias was calculated by subtracting the mean dwell time on neutral pictures from alcohol pictures for each session. Approach bias was calculated by subtracting the mean reaction times from the 'approach alcohol' block from the mean reaction times from the 'avoid alcohol' block in the SRC task for each session. Original scores of the first eye movement percentage toward alcohol cues and craving scores at time 2 were correlated as well. Mean gaze 'dwell time' bias was not normally distributed; therefore, we calculated Spearman correlations (ρ) for this bias with the other variables. For all other correlations, we used Pearson's test (r).

Attentional bias RT and mean gaze 'dwell time' bias were significantly correlated in the alcohol session, $\rho=0.52$, $p=0.01$, and in the placebo session, $\rho=0.45$, $p=0.04$. Furthermore, attentional bias RT and approach bias were stronger correlated in the alcohol session than the placebo session, $r=0.51$, $p=0.03$, $r=0.05$, $p=0.83$, respectively. A greater range for attentional bias RT and approach bias in the alcohol session might be responsible for the increased correlation between those variables. Therefore, we tested whether the correlation in the alcohol session would be much different from the placebo session when measured with a more conservative nonparametric rank test. This was not the case; Spearman's correlation in the alcohol session was 0.40 ($p<0.10$), and in the placebo session was 0.08 ($p>0.50$). Using Steiger's test for calculating the differences between correlations (Steiger 1980), we found that the Pearson correlation was significantly higher in the alcohol session than in the placebo session, $z=1.70$, $p=0.04$, indicating a significant increase in the correlation between these cognitive biases after the alcohol prime dose.

The previous finding is consistent with the difference in correlations between mean gaze 'dwell time' bias and approach bias (alcohol session: $\rho=0.51$, $p=0.03$; placebo session: $\rho=-0.21$, $p=0.40$), $z=2.38$, $p=0.01$. All other correlations within the sessions were nonsignificant (all over $p>0.05$) and did not differ significantly between sessions (all over $p>0.05$). See Table 3 for a correlation matrix of the dependent variables per session.

Discussion

In this study, we found that multiple indices of attentional bias were significantly larger after a low alcohol dose compared with placebo. This effect was apparent in the reaction time latencies during the visual-probe task and in concurrent dwell time measures. In addition, in contrast to the placebo, the percentage of first eye movements toward alcohol cues was higher and significantly above chance level after the alcohol prime dose. Unexpectedly, the approach bias did not differ as a function of alcohol consumption; a significant approach bias for alcohol was found in both sessions. As hypothesized, craving significantly increased after the alcoholic drink, but not after the placebo drink. In line with our hypothesis, correlations between measures of appetitive motivation were mostly higher in the alcohol session than in the placebo session. However, these differences only reached significance for the correlations between attentional bias RT and mean gaze dwell time bias with approach

bias. Compared to earlier research into the effects of alcohol intake on appetitive motivation, our results gave a more detailed insight. This is because we integrated different measures from earlier research (attentional bias RT and craving) and added new ones (eye movement monitoring and approach bias).

The increase in attentional bias after a low alcohol dose is consistent with results of Duka and Townshend (2004) who found an increase after an identical dose. A difference with their study is that they used a shorter stimulus presentation duration of 500 ms, whereas ours was 2,000 ms, showing that the increase in attentional bias for alcohol-related stimuli is maintained when pictures are presented for 2,000 ms. Mean scores of congruent and incongruent trials (Table 2) show that the effect was mainly caused by participants being slower on incongruent trials in the alcohol session compared to the placebo session. This indicates that the prime dose hampered attentional disengagement from alcohol-related stimuli (cf. Koster et al. 2004) at stimulus offset.

In addition to assessing attentional bias through an indirect measure (visual-probe task response latencies), we measured attention directly through monitoring participants' eye movements during the visual-probe task. This allowed us to monitor attention not only at stimulus offset (as with response latencies) but rather during the entire length of the stimulus presentation. The finding that after the alcohol dose, the dwell time and first eye movements toward alcohol cues increased, suggests that both initial engagement and the maintenance or disengagement of attention are sensitive to an activated motivational state. Furthermore, we think that the alcohol dose sensitized the heavy drinkers in such a way that their attentional bias became more automatic, as indicated by the initial orienting of attention to alcohol-related stimuli, and thereby more similar to that of alcoholics (see Noel et al. 2006).

Regarding the SRC task, participants showed an approach bias, although this effect was not significantly influenced by the alcohol prime dose. It is interesting to note that, in a previous study with smokers (Field et al. 2005a), the administration of an alcohol priming dose led to increased attentional bias for smoking-related cues (as inferred from reaction times to probes and gaze 'dwell times'), but did not influence the tendency to direct approach responses toward those cues during the SRC task. Therefore, it seems that alcohol priming doses may increase the 'attention-grabbing' properties of drug-related cues without influencing the tendency to direct rapid approach responses toward those cues. Specifically, approach bias appears to be a more stable construct than attentional bias, in that it is not influenced by an alcohol priming dose. However, approach bias does correlate with aspects of attentional bias, but only when the individual is intoxicated.

Rather than physically approach or avoid stimuli in the SRC task, participants symbolically move a small manikin toward or away from the stimuli. For this reason, one might question the validity of the SRC task for measuring approach and avoidance tendencies. Recent studies suggest, however, that it is not the physical movement toward or away from stimuli that is responsible for the performance on an approach/avoidance task, but the cognitive representation of an approach or avoid action (Markman and Brendl 2005; Lavender and Hommel 2007). Instructing participants to approach by moving the manikin toward stimuli and to avoid by moving it away forms a cognitive representation of approach and avoid. We believe that this representation determines the approach bias that we observed in the present study and in other studies that used the SRC task with tobacco smokers (e.g., Mogg et al. 2003; Bradley et al. 2004).

Craving and first eye movements changed parallel to factors of attentional maintenance, although a direct relation between these factors in terms of correlations was not observed. A possible reason is that there are individual differences in the way different factors of

appetitive motivation react to an alcohol prime dose. Thus, overall, there was an increase in most of our dependent variables after alcohol, but there might be interindividual differences in the extent to which this increase manifests itself in different aspects of self-report and cognitive processing.

In the present study, there were no significant correlations between craving and cognitive biases in both sessions. In this regard, the previous evidence is mixed, as some studies demonstrate a clear relationship between cognitive biases and subjective craving whereas others do not (see the introduction). Some theorists have argued that subjective craving and the incentive-motivational properties of drug-related cues are not always related. Robinson and Berridge (2000) state that "...the neural system responsible for incentive salience attribution can sometimes produce goal directed behavior....in the absence of conscious awareness of "wanting"..." (p. S105). In addition, Wiers et al. (2007) propose a model in which subjective craving is not necessary for biased cognitive processing of drug cues to occur in heavy substance users. We did find an increase in subjective craving, so there seemed to be at least some conscious awareness of "wanting". However, because significant correlations with craving were absent, one may question whether our craving measure and cognitive bias measures tapped the same underlying construct.

In our introduction, we offer one possible explanation for the alcohol prime dose effect, namely, the disinhibition of control. The goal of our study was to specify the effect, not to directly test the disinhibition hypothesis. To test this tentative explanation, further research should correlate individual differences in inhibitory control with individual differences in cognitive bias when participants are both intoxicated and sober.

To conclude, different measures of appetitive motivation react differently to an alcohol prime dose. Whereas subjective craving, attentional maintenance, and initial engagement toward alcohol cues increased, approach bias did not change. We suggest that further research should focus on the differences and similarities between attentional and approach bias in response to alcohol prime doses and their possible mediation by deficits in inhibitory control.

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Table 1
Nonparametric Wilcoxon signed-rank tests of the SIS in alcohol and placebo sessions from time 1 to time 2

	Time 1		Time 2		Comparison of time 1 with time 2	
	Mean	SD	Mean	SD	Z	
Alcohol session						
Lightheaded	14.85	21.94	33.40	25.75	3.06	***
Irritable	9.99	20.16	10.95	16.08	0.51	
Stimulated	30.17	29.53	38.51	23.47	1.92	
Alertness	58.18	19.78	48.18	23.03	2.56	**
Relaxed	55.91	24.27	59.82	25.82	1.29	
Contented	54.29	24.61	51.91	25.51	0.67	
Placebo session						
Lightheaded	11.62	19.41	17.45	23.96	1.96	*
Irritable	16.20	22.62	12.62	14.73	1.30	
Stimulated	27.55	26.04	34.46	27.62	1.85	
Alertness	49.43	27.41	46.07	22.70	1.53	
Relaxed	56.42	19.92	54.97	18.51	0.29	
Contented	52.23	22.84	51.92	21.60	0.35	

Scores are the means and SDs from 100 mm VAS.

* $p<0.05$
 ** $p<0.01$
 *** $p<0.001$.

Table 2

Means and SDs for measures of appetitive motivation during the alcohol and placebo sessions: craving (DAQ), attention (visual-probe reaction times, mean gaze 'dwell time', first eye movement), and approach/avoidance (SRC task reaction times)

	Placebo session		Alcohol session	
	Mean	SD	Mean	SD
Craving				
DAQ score at time 1	2.56	1.02	2.67	0.96
DAQ score at time 2	2.65	1.18	3.04	1.16
Visual-probe task				
Median reaction time on congruent trials (ms)	635	13.2	639	15.8
Median reaction time on incongruent trials (ms)	634	13.3	660	15.3
Mean gaze 'dwell time' on alcohol pictures (ms)	775	129	812	193
Mean gaze 'dwell time' on control pictures (ms)	740	146	709	141
Percentage of first eye movements toward alcohol pictures	49.5	5.40	53.9	8.56
SRC task				
RT during 'approach alcohol' block (ms)	720	102	722	103
RT during 'avoid alcohol' block (ms)	761	105	743	75.3

DAQ is the mean score on the Desires for Alcohol Questionnaire at time 1 (before drink administration) and time 2 (after drink administration), scale 1-7.

Table 3

Correlations between dependent variables for the alcohol and placebo sessions

Measures	1		2		3		4		5	
	A	P	A	P	A	P	A	P	A	P
Attentional bias										
1. Reaction time	-	-								
2. Mean gaze dwell time	0.52*	0.45*	-	-						
3. Percentage of first eye movements toward alcohol	0.11	-0.31	0.30	0.10	-	-				
Other										
4. Approach bias	0.51*	0.05	0.51*	-0.21	0.30	-0.06	-	-		
5. Craving time 2	0.25	-0.09	0.28	0.17	0.04	-0.31	0.21	0.39	-	-

Correlations with mean gaze dwell time bias are nonparametric Spearman correlations. All other correlations are parametric Pearson correlations. A: correlations for the alcohol session, P: correlations for the placebo session.