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Effects of alcohol on attentional mechanisms involved in figure reversals

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Objective  The impairing effects of alcohol on attention are well documented and are thought to involve inhibitory mechanisms. We used ambiguous figures (Face-Vase and Necker cube) to test whether the intentional control mechanism is more vulnerable to the effects of alcohol than the automatic mechanism. Method: Participants were assigned to an alcohol (Study 1, \(N=15\); Study 2, \(N=18\)), placebo (Study 1, \(N=15\); Study 2, \(N=20\)) or control (Study 1 only, \(N=10\)) group. The doses of alcohol were 0.8 g/kg for men and 0.75 g/kg for women. Participants were shown the Face-Vase and Necker cube figures and two variants of each, which were biased in varying degrees towards one interpretation. Study 1 assessed the automatic control mechanism by asking participants to report spontaneous reversals. Study 2 assessed the intentional control mechanism by asking participants to increase reversal rate. Results: In Study 1, reversal rate was similar for all groups, whereas in Study 2, the alcohol group reported more reversals than the control group, although this was true only for the biased versions of the Face-Vase illusion. Conclusions: The effect of alcohol on reversal rate is observed only during intentional reversals of semantically meaningful stimuli and only when the stimulus is biased. Copyright © 2013 John Wiley & Sons, Ltd.

KEY WORDS—alcohol; attention; inhibition; ambiguous figures; figure reversals

INTRODUCTION

Studies of social drinkers suggest that mechanisms of behavioural control are sensitive to the impairing effects of alcohol (Abroms and Fillmore, 2004; Fillmore and Vogel-Sprott, 1999), and this may contribute to acute states of dyscontrol after alcohol. This is at least in part because inhibitory mechanisms are thought to play a crucial role in selection in both motor and perceptual processing. In a given situation, the motor system must select just one appropriate response from the available repertoire, whereas perceptual systems must select just one appropriate interpretation from a range of possibilities that might account for the sensory data. In both systems, inhibition is thought to be responsible for the suppression of the unchosen alternatives, which contributes to behavioural control. Moderate doses of alcohol impair performance on both sensory and motor tasks and are thought particularly to disrupt this inhibitory suppression (e.g. Houghton and Tipper, 1994; Fillmore et al., 1998; Curtin et al., 2001).

There is considerable evidence that alcohol reduces the ability to inhibit inappropriate motor acts (e.g. Fillmore and Weafer 2004; Marczinski and Fillmore, 2005). For example, moderate doses of alcohol impair the ability to inhibit pre-potent responses in tasks such as the stop-signal and go-no-go tasks (de Wit et al., 2000; Abroms et al., 2003). This impairment of pre-potent actions may underlie some of the socially undesirable effects of alcohol, such as increased aggression and risky decision-making (Jentsch and Taylor 1999; Lane et al., 2004; Rose and Duka 2007).

In perceptual processing, alcohol is well known to disrupt performance in tasks that require visual attention to be divided amongst two or more activities (e.g. Koelega, 1995; Fillmore et al., 1998; Curtin et al., 2001). The ability to selectively attend to specific items in a visual scene depends upon inhibition of irrelevant items in an array (Houghton and Tipper, 1994), and alcohol impairs the inhibitory mechanisms that direct attention away from irrelevant stimuli (Fillmore et al., 2000a, 2000b; Tzambazis and Stough, 2000). Alcohol has also been reported to impair the inhibitory processes that usually prevent return to previously attended items in a visual search task (Abroms and Fillmore, 2004). Similarly, alcohol reduces negative priming (Fillmore et al., 2000a). Here, the response to a target is typically slower if the target has appeared as an irrelevant distractor on
the previous trial (Tipper, 1985; Houghton and Tipper, 1994). Alcohol is thought to reduce this effect by disrupting an inhibitory process that normally suppresses distracting stimuli.

Less is known about the conditions that moderate the effects of alcohol on inhibitory mechanisms in attention. In particular, one important issue is whether the affected mechanism is intentionally controlled or automatic (Fisk and Schneider, 1981; Marzi, 1999; Shimojo et al., 1999). Intentional inhibitory mechanisms are under conscious control, whereas automatic inhibitory mechanisms operate in an involuntary fashion in response to external stimuli. Some previous research has shown that intentional behaviours might be more vulnerable to alcohol than automatic behaviours (Holloway, 1995; Fillmore and Vogel-Sprott, 2006), whereas other work suggests that intentional and automatic mechanisms of attention are equally vulnerable to moderate doses of alcohol (Holloway, 1995).

To our knowledge, only one study has directly compared the effect of alcohol on automatic and intentional inhibitory mechanisms of visual attention. The study assessed the effects of alcohol on two selective attention tasks that involved eye movements to visual targets: a saccadic interference task involving automatic inhibition and a delayed oculomotor response task requiring intentional inhibition (Abroms et al., 2006). Alcohol at doses of 0.45 and 0.65 g/kg reduced intentional inhibitory control over attention but had no effect on automatic inhibitory influences. However, one limitation of this study is that eye movements may not perfectly reflect visual attention. For example, although eye movements have been taken to indicate shifts of visual attention (e.g. Posner, 1980), there are conditions under which the eyes may be directed to one location while attention is directed to another (Godijn and Theeuwes, 2003).

The present studies aimed to investigate the effect of alcohol on automatic and intentional inhibitory mechanisms by assessing the effect of alcohol on the perception of ambiguous figures. Ambiguous figures, such as the ‘Necker cube’ give rise to two distinct percepts. When viewing ambiguous figures, there is insufficient information in the retinal array to produce a single stable percept, and therefore, our perception of the image flips between each of the possible interpretations. Ambiguous figures provide a novel way to assess mechanisms of attention. Previously, comparisons between the impairment of automatic and intentional mechanisms following alcohol consumption have been made across different experimental conditions and modalities. Here, ambiguous figures allow these mechanisms to be compared using a single stimulus type, eradicating the need for cross-modality comparisons.

Attention has long been thought to play a role in figure reversals (e.g. von Helmholtz, 1962; Liebert and Burk, 1985; Horiguchi and O’Leary, 1993; Gomez et al., 1995; Toppino, 2003; Meng and Tong, 2004), and the selection and temporary stability of one interpretation is thought to depend upon inhibition of the other (von Helmholtz, 1962; Fisher, 1967; Giris and others, 1977). Moreover, this inhibition is thought to involve both automatic (Köhler and Wallach, 1944; Blake, 1989) and intentional components (Strüber and Stadler, 1999) that can be manipulated by instruction. For instance, instruction to increase reversal rate (flipping from one interpretation to the other) is thought to activate intentional control mechanisms (e.g. Pelton and Solley, 1968; Seth and Reddy, 1979; Peterson and Hochberg, 1983; Liebert and Burk, 1985), whereas in the absence of such an instruction, control is assumed to depend only upon automatic control mechanisms (Strüber and Stadler, 1999). If alcohol disrupts inhibitory processes in attention, then it should make each interpretation less stable and so should increase reversal rate. However, on the basis of the results of previous work (Abroms et al., 2006), this effect should be evident when there is intentional control over figure reversals but not when there is only automatic control.

Alcohol should also affect the perceptual stability of the figure. The two interpretations of the ambiguous figure compete with each other to be seen, so the addition of a bias towards one interpretation results in one interpretation being more dominant and produces fewer reversals between interpretations because the alternative interpretation becomes easier to suppress (Giorgiades and Harris, 1997; Toppino, 2003). But if alcohol weakens inhibition, then this suppressive effect of bias should be reduced.

It has also been reported that the intentional control of reversal rate is stronger with more semantically meaningful ambiguous figures (Strüber and Stadler, 1999), suggesting that high-level semantic processes are indeed more susceptible to conscious intervention than are the relatively low-level ‘syntactic’ processes involved for example in depth perception. The following studies therefore introduced varying degrees of bias into both a semantically meaningful figure (the Rubin Face-Vase) and a purely syntactic figure (the Necker cube).

Study 1 compared the effects of a moderate dose of alcohol, a placebo and a no-drink control condition upon spontaneous reversals of biased and ambiguous versions of the Face-Vase and the Necker cube. The
no-drink control group was included to eliminate the expectancy effects associated with alcohol intake (Marczinski and Fillmore, 2005). Study 2 introduced an intentional component by asking participants to try actively to reverse their interpretation of the stimuli. Taken together, the two studies therefore allow us to tease apart the effects of alcohol on intentional and automatic aspects of attention.

STUDY 1: EFFECTS OF ALCOHOL ON AUTOMATIC CONTROL MECHANISMS INVOLVED IN FIGURE REVERSALS

Method

Participants. Forty young social drinkers with normal or corrected-to-normal vision were recruited from Birmingham University through the Psychology online research participation scheme. They were told they were taking part in a study looking at the effects of alcohol on the perception of ambiguous stimuli. Taken together, the two studies therefore allow us to tease apart the effects of alcohol on intentional and automatic aspects of attention.

Participants who were the first to volunteer were 18–35 years old, had drunk more than seven units of alcohol on at least one occasion prior to testing, drank at least eight units of alcohol per week, were currently in good health, had no past or present drug and/or alcohol dependence, were not currently taking any prescribed and/or non-prescribed medication that would be affected by alcohol (excluding the contraceptive pill), had never suffered a serious head injury with loss of consciousness, had no neurological disorders such as epilepsy, had no history of psychiatric illness with or without treatment, were not pregnant or possibly pregnant, did not meet the criteria on the Michigan Alcohol Screening Test (MAST; see succeeding paragraphs), had not eaten and/or drunk and/or smoked within 1 h prior to testing but had eaten breakfast that day, had not consumed alcohol and/or recreational drugs within 12 h prior to testing and had a BrAL of zero upon arrival at the experiment. The study conformed to the British Psychological Society guidelines for conducting research with human participants.

Design. Participants were allocated pseudo-randomly to one of three groups so that the groups were matched for age and gender: an alcohol group (6 men and 9 women; mean = 21.4 years, sd = 2.41, average self reported consumption of 10.00 units of alcohol per week), a placebo group (7 men and 8 women; mean = 21.4 years, sd = 2.35, average self reported consumption of 15.13 units of alcohol per week) or a no-drink control group (6 men and 4 women; mean = 22.2 years, sd = 3.29, average self reported consumption of 14.70 units of alcohol per week).

The ambiguous figures were presented in two blocks, one containing three Necker cube stimuli and the other containing three Face-Vase stimuli. Within each block, the unbiased figures were always presented first to minimise priming effects reported elsewhere (Long and Toppino, 2004). The order of block presentations was fully counter balanced.

Screening tools. Lifestyle questionnaire. Participants completed a ‘Lifestyle Questionnaire’, which was used to compile demographic information. It consisted of 16 questions about participant age, gender, highest level of educational qualification, number of years in full time education, amount of alcohol consumed (units per week), whether they smoked cigarettes and if so, the number of cigarettes smoked per day and time since last use, the number of cups of tea and/or coffee consumed per day and time since last use, details of any prescribed and non-prescribed medication currently used, past or present psychiatric illnesses, any serious head injuries with loss of consciousness and any neurological disorders.

Alcohol Use Questionnaire. (AUQ). AUQ Score. The AUQ (Mehrabian and Russell, 1978) asks questions about participants’ habitual use of alcohol. Participants are asked to use the previous 6-month period as a guide to help them answer the questions, rather than trying to remember the precise quantities of alcohol consumed. The AUQ yields a score based on number of alcoholic drinks per week (wine, questions 1–3; beer, questions 4–6; spirits, questions 7–9), speed of drinking (drinks per hour, question 10), number of times intoxicated in the last 6 months (question 11) and the percentage of times intending to be intoxicated (question 12). There was no exclusion criterion for this measure; rather, the AUQ score was used to ensure that there was no difference amongst the groups on the basis of their habitual use of alcohol.

Binge Score. A binge score was calculated to assess the relationship between drinking patterns and alcohol intake using information given in the AUQ about the number of drinks per hour, the number of times intoxicated in the last 6 months and the percentage of times intending to be intoxicated (Townshend and Duka, 2002). There was no exclusion criterion for this measure; the Binge score was used to ensure that there was no difference amongst the groups on the basis of their pattern of drinking.
**Michigan Alcohol Screening Test (MAST).** The MAST (Selzer, 1971) consists of 22 questions to identify possible alcohol misuse. The questions require ‘yes’ or ‘no’ responses, which are scored by allocating 1 point to each ‘yes’ answer and 0 points for each ‘no’ answer (apart from questions 1 and 4 where 1 point is allocated to a ‘no’ response and 0 points to a ‘yes’ response). The total score is used to assess possible drinking problems, a score of 0–2 indicating no apparent problem, 3–5 early or middle problem drinkers and 6 or more indicating problem drinkers. Those with a score of 6 or above were excluded from further testing.

**Alcohol administration.** Participants in the alcohol condition were given a drink containing one part vodka (men: 0.8 g/kg, women 0.75 g/kg of vodka, 37.5% concentration), one part non-alcoholic apple schnapps (The LoNo drinks company, Cirencester, UK) and three parts Indian tonic water. Participants in the placebo condition were given drinks containing one part non-alcoholic apple schnapps and four parts Indian tonic water, which has been shown to be an effective placebo (Higgs *et al*., 2008; Birak *et al*., 2010). Those in the no-drink condition did not receive drinks prior to testing.

**Materials and tasks.** The ambiguous figures used were the Necker cube (Necker, 1832) and the Face-Vase illusion (Rubin, 1958), see Figure 1(a and d). Three versions of each ambiguous figure were used, the original and two biased versions.

**Necker cube stimuli:** In addition to the ambiguous version of the figure, in which all lines were equally bright, two biased versions were used in which the luminance of three of the lines was reduced by 30% (Figure 1(b)) or 53% (Figure 1(c)) to bias interpretation towards the front face defined by the other lines. All Necker cube stimuli measured 8 × 8 cm.

**Face-vase stimuli:** Two biased versions of the Face-Vase illusion were used in which the central vase interpretation was emphasised by decreasing its luminance by 30% (Figure 1(e)) or 50% (Figure 1(f)), thus increasing its salience. Stimuli measured 9 × 9 cm and were presented on a white background with black contour lines distinguishing the components of the face and the vase (with the addition of grey to fill the vase component in the biased conditions).

The experiment was run on a Packard Bell AMD Turion™ (Sunnyvale, CA, USA) 64 laptop (1.80 GHz, 44MB), with the stimuli presented on the computer screen (resolution of 1024 × 768 pixels (60 Hz) 32 bit) at a viewing angle of 7.6° × 7.6° for the Necker cube stimuli and 8.5° × 8.5° for the Face-Vase stimuli.

Each ambiguous figure was presented for 1 min. Participants were asked to report spontaneous reversals

![Necker cube stimuli](image1)

![Face-vase stimuli](image2)

Figure 1. The ambiguous figures used for the experiment, including the two unbiased stimuli used for both the Necker cube and Face-Vase illusions (a and d), the two light biased stimuli (b and e) and the two dark biased stimuli (c and f)
during the 1-min presentation time and not to intentionally reverse their interpretation. They made their responses by using the numeric keys 1 and 2 on the laptop’s keyboard by holding down the appropriate key whilst experiencing the corresponding interpretation. For the Necker Cube trials, key 1 represented the front face facing left, and key 2 represented the front face facing right. For the Face-Vase trials, key 1 represented the faces, and key 2 represented the vase. Participants were shown an example of each original ambiguous figure and encouraged in the instruction sheet to experience both interpretations prior to testing. Previous research has shown that this reduces any inherent bias (Leeper, 1935; Botwinick, 1961; Georgiades and Harris, 1997).

The programme DMDX (Forster and Forster, 2003) was used to run the experiments, including the presentation of the stimuli, recording the number of reversals reported and the time spent experiencing each interpretation.

Procedure

Participants were asked to eat breakfast before arriving for the experiment but not to eat, drink or smoke within the 1-h period before they were due to be tested. Upon arrival, participants were breathalysed (Lion alcometer breathalyser, model S-D2; Lion Industries, Barry, Wales) and then weighed. Participants then completed, in order, the Lifestyle Questionnaire, AUQ and the MAST questionnaires. The drinks were divided equally amongst three glasses with the instruction to drink one glass every 5 min. They had 15 min to drink all three drinks to produce a peak BrAC after approximately 25 min, at which time the glasses were removed and participants were given a 10-min rest period before being breathalysed again.

Participants then completed the ambiguous figures task, after which they were breathalysed again. Participants took part in one session lasting approximately 1 h with one participant per session. Test sessions took place in a laboratory containing a desk, chair and a laptop. At the end of the session, participants were debriefed and asked whether they had any questions about the study.

Data analysis. One-way ANOVAs and chi-squared tests were used to analyse group differences on the basis of the demographic information and questionnaire responses provided by the Lifestyle, AUQ and MAST questionnaires. Mixed ANOVAs were used to analyse performance in the ambiguous figure task. Where post hoc tests were conducted, Bonferroni corrections were used to deal with multiple comparisons. All statistical tests were performed using SPSS (Chicago, IL, USA).

Results

Demographics. Participant demographic and test results are summarised in Table 1. One-way ANOVAs and chi-squared tests revealed no age, gender, weight or education differences between the groups. There were no significant differences between the groups for units of alcohol per week, caffeine use, cigarettes use or scores on the MAST and AUQ.

Breath alcohol concentration. All breath alcohol levels were 0 at the beginning of the session. There was a significant difference between the groups after

<table>
<thead>
<tr>
<th>Group mean</th>
<th>Control</th>
<th>Placebo</th>
<th>Alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 10)</td>
<td>(n = 15)</td>
<td>(n = 15)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>22.2 (3.29)</td>
<td>21.4 (2.35)</td>
<td>21.4 (2.41)</td>
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<tr>
<td>Gender (ratio male : female)</td>
<td>6:4</td>
<td>7:8</td>
<td>6:9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.03 (11.99)</td>
<td>67.72 (10.29)</td>
<td>65.08 (6.66)</td>
</tr>
<tr>
<td>Education (years)</td>
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<td>16.07 (2.15)</td>
<td>15.73 (2.71)</td>
</tr>
<tr>
<td>Alcohol (units per week)</td>
<td>14.70 (10.26)</td>
<td>15.13 (11.06)</td>
<td>10.00 (5.49)</td>
</tr>
<tr>
<td>Caffeine (ratio Yes : no)</td>
<td>6:4</td>
<td>9:6</td>
<td>14:1</td>
</tr>
<tr>
<td>Cups per day</td>
<td>3.33 (1.97)</td>
<td>2.44 (1.01)</td>
<td>1.93 (1.27)</td>
</tr>
<tr>
<td>Hours since use</td>
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<td>11.89 (11.91)</td>
<td>13.29 (16.69)</td>
</tr>
<tr>
<td>Cigarettes (ratio yes : no)</td>
<td>1:9</td>
<td>2:13</td>
<td>2:13</td>
</tr>
<tr>
<td>Per day</td>
<td>5.00 (0)</td>
<td>3.00 (1.41)</td>
<td>2:13</td>
</tr>
<tr>
<td>Hours since use</td>
<td>2.00 (0)</td>
<td>6.50 (7.78)</td>
<td>2:13</td>
</tr>
<tr>
<td>MAST Score</td>
<td>1.40 (1.17)</td>
<td>1.73 (1.28)</td>
<td>1.07 (0.59)</td>
</tr>
<tr>
<td>AUQ Score</td>
<td>38.68 (26.79)</td>
<td>1.73 (1.28)</td>
<td>35.39 (20.56)</td>
</tr>
<tr>
<td>Binge Score</td>
<td>26.08 (24.86)</td>
<td>24.49 (17.23)</td>
<td>24.72 (17.71)</td>
</tr>
</tbody>
</table>

Table 1. Participant means, ANOVA and chi-squared results of between group comparisons (standard deviations in parentheses).

MAST, Michigan Alcohol Screening Test; AUQ, Alcohol Use Questionnaire.
drink consumption (alcohol group = 0.42 mg/l BRAlc) [F(2, 37) = 170.57, p = 0.01] and at the end of the session (alcohol group = 0.20 mg/l BRAlc) [F(2, 37) = 93.03, p = 0.01].

**Task performance.** To control for individual differences in reversal rate, the data for each participant were first normalised by dividing the total number of reversals by the total viewing time between the first and last responses (Zheng and Ukai, 2006). The results are summarised in Figure 2(a and b).

A mixed ANOVA was conducted on the average reversal rate, with group (Alcohol, Placebo or No-drink Control) as the between-subjects factor, and two within-subjects factors, Bias (Ambiguous, Light Bias and Dark Bias) and Stimulus Type (Face-Vase or Necker Cube). Analysis revealed a reliable main effect of Stimulus Type [F(1, 37) = 8.11, p = 0.01], with more reversals reported for the Face-Vase illusion. The main effect of Bias was significant [F(2, 74) = 7.00, p = 0.01], with more reversals reported for the ambiguous figures than for the biased figures, supporting our expectation that bias should stabilise the interpretation of the figures. However, there was no significant Group × Bias interaction [F(4, 74) = 0.43, p = 0.77]. Moreover, there was no significant main effect of Group [F(2, 37) = 0.81, p = 0.45] and no other significant interaction (Type × Group [F(2, 37) = 0.34, p = 0.71], Bias × Type [F(2, 74) = 1.80, p = 0.17]. Bias × Type × Group [F(4, 74) = 2.11, p = 0.09]). Alcohol appears to have no effect on the spontaneous reversal of ambiguous figures.

These results are supported by an analysis of the time spent perceiving each interpretation of the figures. The average percentages of time spent perceiving whichever interpretation was preferred by each participant in each condition are shown in Figure 3(a and b).

A mixed ANOVA on these data revealed a reliable main effect of Bias [F(2, 74) = 15.55, p < .001], confirming an increasingly biased interpretation with increasing stimulus bias. However, none of the other main effects or interactions approached significance, except for a non-significant trend of Group [F(2, 37) = 2.43, p = .102], suggesting that alcohol tended to stabilise perception by increasing the time spent perceiving one particular interpretation.

**STUDY 2: EFFECTS OF ALCOHOL ON INTENTIONAL ATTENTIONAL MECHANISMS INVOLVED IN FIGURE REVERSALS**

**Methods**

Having established that expectancy effects were minimal in Study 1, the No-drink Control condition was omitted from Study 2. Thirty-eight young social drinkers were recruited, screened and briefed as in Study 1 and were allocated pseudo-randomly to two
groups: an alcohol (9 men and 9 women; mean = 24.3 years, sd = 5.81, average self reported consumption of 14.86 units of alcohol per week) and a placebo group (8 men and 12 women; mean = 21.9 years, sd = 2.63, average self reported consumption of 12.1 units of alcohol per week). Alcohol and the placebo groups were prepared and administered as in Study 1. The stimuli and tasks were as described in Study 1 except that reversal rate was brought under intentional control by asking participants to make as many perceptual reversals as possible but to respond only when they were experiencing a particular interpretation.

Results

Demographics. Participant demographic and test results are summarised in Table 2. Independent t-tests and chi-squared tests revealed no age, gender, weight or education differences between the groups. There were no significant differences between the groups for units of alcohol per week, reported caffeine consumption, cigarettes use and scores of the MAST and AUQ.

Breath alcohol concentration. All breath alcohol levels were 0 at the beginning of the session. There was a significant difference between the groups after drink consumption (alcohol group = 0.59 mg/l BRAlc) \( t(35) = 13.11, p = 0.01 \) and at the end of the session (alcohol group = 0.31 mg/l BRAlc) \( t(35) = 21.22, p = 0.01 \). Data from one participant were removed because of a false reading. To check whether the breath alcohol levels achieved in Study 2 differed from those in Study 1, we conducted an ANOVA with time after alcohol consumption and Study as factors. There was no main effect of Study on breath alcohol levels, \( F(1, 76) = 0.023, p = 0.9 \).

Task performance. Average reversal rates are summarised in Figure 2(c and d). A mixed ANOVA revealed no significant main effects of Group \( F(1, 36) = 2.86, p = 0.10 \) or Bias \( F(2, 72) = 1.98, p = 0.16 \). However, there was a significant Group by Bias interaction \( F(2, 72) = 4.46, p = 0.03 \). Follow-up contrasts to explore the source of this interaction revealed no significant differences between the groups for the ambiguous stimuli \( t(36) = 0.82, p = 0.42 \) and the light bias stimuli \( t(36) = 1.76, p = 0.09 \), but there was a significant difference between the groups for the dark bias stimuli \( t(36) = 2.00, p = 0.05 \). Further follow-up contrasts showed that the alcohol group reported a significant difference in figure reversals between the ambiguous and light bias \( t(17) = -2.09, p = 0.05 \) and ambiguous and dark biased conditions \( t(17) = -2.17, p = 0.05 \). However, the alcohol group did not report a significant difference in the number of figure reversals between the light and dark biased conditions \( t(17) = -0.43, p = 0.67 \), whereas the Placebo group did not report a significant difference.

Figure 3. Percentage time in preferred interpretation as a function of stimulus bias: left column (a, c), Study 1 Face-Vase figure; right column (b, d) Necker cube; top row (a, b), Study 1 automatic reversals; bottom row (c, d), Study 2 intentional reversals.
in reversals between the ambiguous and light biased condition $[t(19) = 0.46, p = 0.65]$, ambiguous and dark biased condition $[t(19) = 0.84, p = 0.41]$, or the light and dark bias condition $[t(19) = 1.00, p = 0.33]$. As in Study 1, the main effect of Stimulus Type was significant $[F(1, 36) = 15.41, p = 0.01]$, with more reversals for the Face-Vase stimuli than the Necker cube stimuli. The Type by Group interaction approached significance $[F(1, 36) = 3.89, p = 0.06]$. Post hoc tests show that there were no group differences for the Necker Cube figures $[t(36) = 0.72, p = 0.48]$, but the difference for the Face-Vase figures was marginally significant once the Bonferroni correction was applied $[t(36) = 2.18, p = 0.03]$. There were no significant interactions for Bias $\times$ Type $[F(2, 72) = 0.20, p = 0.76]$ or Bias $\times$ Type $\times$ Group $[F(2, 72) = 1.60, p = 0.21]$. Although reversal rate is clearly affected by alcohol, at least for the Face-Vase stimulus, biasing the stimulus had little effect in the other conditions. For example, we expected reversal rate to decrease with bias in the placebo condition as it did in Study 1, but there is no evidence of this trend here. This point is further underlined by the percentage of time spent in the preferred interpretation, which was remarkably constant across all conditions (Figure 3(c and d)). A mixed ANOVA on these data confirmed that there were no reliable effects of Stimulus Type, Bias or Alcohol level, and no reliable interactions between them.

**DISCUSSION**

In Study 1, without the explicit instruction to maximise reversals, a moderate dose of alcohol had no substantial effect and, if anything, tended to reduce spontaneous reversal rate. This contrasts with Study 2, where a moderate dose of alcohol resulted in increased intentional reversals of ambiguous stimuli, although the effect was significant only for the biased versions of the Face-Vase figure. The breath alcohol levels achieved in both studies were comparable and similar to those observed in other studies reporting effects on inhibition (Casbon et al., 2003; e.g. Birak et al., 2011). Therefore, the lack of effect of alcohol in Study 1 is unlikely to be explained by an ineffective level of alcohol in the blood in that study.

These results are not compatible with a general effect of alcohol, such as enhanced compliance with instructions, increased positive response bias, reduced information capacity (Johnston and Heinz, 1978; Reisberg, 1983; Reisberg and O’Shaughnessy, 1984) or increased impulsivity (Mulvihill et al., 1997; Dougherty et al., 1999, 2000; Marcinski et al., 2007), because the effect occurs only with the biased version of the Face-Vase stimulus but not the Necker cube. Moreover, an effect of alcohol on task fatigue cannot account for the results because the order of presentation of stimuli was counterbalanced, and yet we observed a selective effect on the Face-Vase stimulus. This cannot be explained either by the participants’ expectations of an alcohol effect (Marczinski and Fillmore, 2005), as confirmed by the responses in the ‘No-drink’ condition of Study 1.

Alcohol also has well known effects on basic visual processes. Visual acuity, accommodation, colour vision and motion perception are not affected by moderate acute doses of alcohol (Bates, 1989; Hill and Toffolon1990; MacArthur and Sekuler, 1982, McNamee, Tong, and Piggins, 1980; Wallgren and Barry, 1970; Watten and Lie, 1996). But contrast
sensitivity is degraded (Nicholson, Andre, Tyrrell, Wang, and Leibowitz, 1995; Pearson and Timney, 1998) and there is some evidence for impairment in depth perception (Watten and Lie, 1996; Wegner and Fahle, 1999). Eye movements are also slowed (Holdstock and de Wit, 1999). However, it is unlikely that general effects of alcohol on visual processing can explain the selective nature of the present findings.

One further possibility is that we observed a general effect of alcohol that was dependent upon the ease with which participants were able to reverse the Face-Vase figure compared with the Necker cube. However, reversal rates were broadly comparable for both types of figure, suggesting that there was no substantial difference in the difficulty of the tasks, and any difference in task difficulty should affect both spontaneous and intentional conditions rather than only the intentional condition, as observed here. Indeed, even if participants did find some conditions more difficult than others, we would argue that such differences are the predictable qualia of the disruption to inhibitory processes.

Instead, our results are consistent with previous reports that alcohol affects performance by disrupting an inhibitory process involved in stabilising the perceived interpretation of ambiguous figures (Abroms et al., 2006; Fillmore and Vogel-Sprott, 2006; Holloway, 1995). Importantly, this effect occurs only for the Face-Vase figure and only when reversals are intentionally controlled. This supports earlier work suggesting that intentional control is more effective with semantically meaningful stimuli (Strüber and Stadler, 1999) and also suggests that lower-level inhibitory processes are less vulnerable to disruption by alcohol. Nevertheless, it will be important in the future to examine this proposition by testing the effect of alcohol on a greater range of semantically meaningful and syntactic stimuli.

A ‘disruption of inhibition’ account also complements findings using the negative priming technique. In negative priming, the response to an initial ‘prime’ stimulus slows the response to a subsequent ‘probe’. It occurs when the correct response to the probe is a response that must be suppressed on the prime trial, and it is thought that this suppression depends on an inhibitory mechanism (Houghton and Tipper, 1994; Tipper, 1985). Studies have shown that a moderate dose of alcohol reduces negative priming, presumably by disrupting this inhibitory mechanism in a way similar to that proposed here (Fillmore et al., 2000a).

There remains one unexpected aspect of our results. We varied the luminance of some parts of the stimuli in an attempt to bias the percept by strengthening one interpretation at the expense of the other. There is some evidence that this manipulation did produce the expected reduction in reversal rate—for example, the effect was reliable in Study 1—but the reduction is slight. Similarly, although we expected bias to encourage participants to favour one particular interpretation of each figure, their responses were more idiosyncratic. When this was taken into account, Study 1 did show an increased tendency to favour one interpretation as bias increased, but there was no such effect in Study 2. One possible explanation of these apparent anomalies is that our manipulation of the Face-Vase did not introduce the intended asymmetry but instead simply made the two interpretations less different from each other. Such a reduction in the contrast between the two interpretations was apparently not sufficient by itself to reduce reversal rate, but it may have reduced the amount of inhibition required to switch between them to the extent that a further reduction due to alcohol was, under the appropriate conditions, sufficient to produce an increased reversal rate.

In summary, we present data from a novel paradigm that are consistent with suggestions from previous work that alcohol impairs inhibitory processes important in the allocation of attention (Houghton and Tipper, 1994; Fillmore et al., 1998; Fillmore et al., 2000a). The use of the ambiguous figures paradigm offers a new approach to investigate the effects of alcohol on cognitive processes, and the data presented here suggest that it would be profitable to examine the effect of alcohol on a broader range of ambiguous stimuli to define the conditions under which alcohol affects image stability. Convergence of data to suggest that alcohol has specific effects on inhibitory processes involved in guiding attention is significant because many higher cognitive functions rely on such processes (Abroms and Fillmore, 2004). Alcohol is known to have a more general impairing effect on a variety of behaviours that rely on inhibitory control such as appropriate social behaviour and risk taking (Jentsch and Taylor, 1999; Lane et al., 2004; Rose and Duka, 2007). Future studies could be directed towards investigation of how the effects of alcohol on attention are related to its effects on behavioural control more generally.

CONFLICT OF INTEREST
The authors have declared that there is no conflict of interest.
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