Title: Measuring inhibitory processes for alcohol-related attentional biases: introducing a novel attentional bias measure

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Measuring inhibitory processes for alcohol-related attentional biases: introducing a novel attentional bias measure

Abstract

Introduction: Attentional biases for alcohol related information (AB) have often been reported for heavy drinkers. These attentional biases have been found to have predictive value regarding relapse in abstaining alcoholics. Similarly impaired inhibitory processes have also been found to be associated with heavy drinkers. This paper describes a new experimental paradigm that can be utilised to investigate attentional bias towards alcohol-related visual stimuli, specifically the ability to inhibit the orientation of initial and sustained attention, towards peripherally appearing stimuli. In this way we hope to study a novel aspect of attentional biases and so how they relate to substance abuse. *Methods:* We used a novel eye-tracking task which aims to measure inhibitory processes for AB. The experiment utilised a gaze contingency paradigm to measure the compulsion to process or attend to alcohol stimuli. 86 undergraduate participants were recruited (31 males; 55 females), aged 18–49 years (m=20.88;sd=4.52). A 'break frequency' variable was computed for each participant. This was number of times participants tried to look at peripheral stimuli. We argue that this variable is a direct measure of how distracting peripheral stimuli were. *Results:* It was found that reported alcohol use was associated with the eye-tracking break frequency measure of inhibitory control. Thus, heavy drinking may be associated with decreased inhibitory control and increased attentional bias. *Conclusions:* Results suggest that attentional bias is not just a process of stimuli becoming prioritised, but also stimuli becoming compulsory to attend and process.

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1. Introduction

Alcohol abuse leads to attentional biases for alcohol-related information (AB), so that abusers' attention is more readily directed towards alcohol-related information and it is more difficult for them to disengage attention from such information. There is extensive evidence for AB (e.g. Sharma, Albery, & Cook, 2001). Cox, Fadardi, and Pothos (2006) reviewed 18 studies utilising the alcohol version of the Stroop task, and concluded that alcohol-Stroop interference can discriminate between broad categories of drinkers i.e. heavy vs. light drinkers. Several other paradigms purport to reveal AB, or related cognitive biases, such as the dot-probe task (MacLeod *et al.*, 1986), memory tasks (Jones & Schulze, 2000; Palfai & Ostafin, 2003; Stacy, 1997), and conceptual structure measures (Rather *et al.*, 1992). Moreover, AB can predict clinical outcomes. Cox *et al.* (2002) showed that alcoholics in treatment who showed an increased alcohol-Stroop bias during treatment were more likely to relapse three months later. Cox, Pothos, and Hosier (2007) found that alcohol-Stroop biases prospectively predicted a reduction in the number of drinking days in a group of excessive drinkers. Field and Eastwood (2005) found that participants who demonstrated increased attention to alcohol-related stimuli had increased alcohol consumption on a subsequent taste-test. Furthermore, there is evidence that training abstinent alcoholics to avoid alcohol-related stimuli increased latency to relapse (Schoenmakers et al., 2010). Such results suggest an important role for AB in substance abuse (Waters & Feyerabend, 2000).

Of measures of AB, the alcohol-Stroop task is the most common. A robust finding (Cox *et al.*, 2006; Sharma, Albery, & Cook, 2001) is that heavy alcohol drinkers (but not light drinkers) take longer to name the ink colour of alcohol-related words than neutral words. Results from the alcohol-Stroop task tend to be interpreted more as relating to sustained attention, as opposed to initial attentional orientation; i.e. the alcohol-Stroop measures the extent of captivating attention, rather than grabbing attention. Such considerations partly motivated the development of the dot-probe task (MacLeod *et al.*, 1986). However, a complication within the task involves the use of large stimulus onsets (SOAs). In such cases, a participant may attend to e.g. the alcohol stimulus, then to the neutral stimulus, then back to the alcohol stimulus etc. (Posner & Cohen, 1984; Rafal, Davies, & Lauder, 2006). Therefore, it is possible to infer AB using the dot-probe, however, we cannot be completely certain of the location of attention from trial onset until a response is prompted. In practice, with sufficiently short SOAs, the dot-probe task can provide a mostly robust measure of initial orientation of attention.

It may seem that between initial and sustained attention, tasks like the Stroop and the dot-probe cover all major facets of AB, but this is not so. Such approaches are less informative regarding another key issue, of exactly how *compulsory* is the orientation of attention towards alcohol-related stimuli, for alcohol abusers (Field, 2010). Relatedly, it seems pertinent to examine the degree to which an alcohol abuser is unable *not* to process an alcohol-related stimulus. Put more simply, exactly how distracting will an alcohol-related stimulus be for an alcohol abuser? Current measures allow for a free processing of the stimuli as participants are encouraged to attend to the stimuli, so that anyone with even a vague interest in the alcohol stimuli may attend to the stimuli. This approach may introduce inherent noise into such measures of AB. A measure where participants are instructed to avoid stimuli may yield a more conceptually simple measure of attentional allocation, as an inability to inhibit the orientation of attention toward a stimulus would represent a compulsory AB.

Current measures of AB do not address this critical issue, even though poor inhibitory control is an established theme in research relating to excessive drinking (Cox & Klinger, 2004; Wiers *et al.*, 2007). For example, it has been suggested that elevated impulsivity and diminished inhibition of alcohol abusers could lead to difficulty in controlling responses to alcohol-related stimuli. Therefore, it is beneficial to develop a measure of AB which directly concerns inhibitory processes, as inhibitory processes are clearly a feature of substance abuse. Within heavy drinkers a positive correlation between impulsivity and AB has been observed (Field, Christiansen, Cole, & Goudie, 2007), suggesting that impulsive individuals are less likely to resist the attention-grabbing properties of alcohol-related stimuli. These findings imply a close relationship between attentional allocation and response inhibition. Lack of inhibitory control possibly relates to existing demonstrations of AB and related theory for alcohol abuse. Through incentive-motivational processes substance-related stimuli become attractive, which leads to a bottom-up allocation of attention. ABs therefore are the product of attention being guided towards attractive stimuli, for an alcohol abuser. A top-down control system could inhibit such attentional processes, so overriding early stage attentional allocation and, plausibly, preventing AB. So, if we accept that ABs are involved in substance abuse maintenance (e.g. Field & Cox, 2008; Robins & Ehrman, 2004), then it is important to understand inhibitory processes in early stage attentional allocation.

The current study aims to directly link failures of inhibitory control involving alcohol-related stimuli and corresponding AB. Weafer and Fillmore (2012) used a go/no-go paradigm, to measure inhibition for alcohol-related stimuli. They found that inhibitory failures were more common after a pre-exposure with alcohol-related stimuli (see also Noel, et al., 2005; Fleming & Bartholow, 2014). But, the empirical measurement of such failures in inhibitory control were measured in a task separate to that of AB. Ideally, we need a measure of failures of inhibitory control as a direct result of AB. Recent studies (Jones & Field, 2013; Noel et al., 2013) have developed and tested anti-saccade based tasks to measure attentional inhibitory mechanisms in relation to alcohol cues. Noel et al (2013) found that alcohol use was associated with an impaired ability to inhibit prepotent responses on cognitive tasks which included the anti-saccade task. The antisaccade task, which is used to measure inhibition for reflexive saccadic eye movement, requires the participant to fixate on a motionless target. Stimuli are then presented on the left or right side of the area of fixation. The participant is given instructions to direct attention towards or away from the presented stimuli, e.g. if a stimulus is presented on the left and the participant is instructed to look away from the stimulus, then the participant must look right – failure to do so results in an error. Previous research has also revealed deficits in attention control of this sort in individuals with high generalised trait anxiety (Garner et al, 2009, 2011; Ansari et al, 2008). However, such a task is limited in that stimulus presentation times are typically short and the antisaccade task has been observed to be difficult to execute consistently, as adult controls do not perform at ceiling (see Roberts, Hager, and Heron, 1994). In the present work, we extended the antisaccade task, in a way which we think suitably covers the requirements for measuring failures of inhibitory control, relating to AB.

We employed an attention fixation task, similar to an antisaccade task, during which participants were instructed to attend to a particular fixation target on a computer screen. While the participant was attending to the fixation target, other visual stimuli appeared on various locations on the computer screen. Even though the participant might be aware of the presence of these distractor stimuli (through peripheral vision), his/her instructions were clearly to only attend to the fixation target. One important innovation in our task relates to how the requirement to attend only to the fixation target was enforced: if the participant did attend to the peripheral distractor stimuli, the stimuli would disappear, for as long as the participant's gaze was directed away from the fixation target. With this innovative paradigm, a participant has no incentive to process the distractor stimuli at all. Under such circumstances, discouraging as much as possible lapses in attention away from the fixation target, we can study exactly how distracting alcohol-related stimuli can be for excessive drinkers, compared to broadly matched neutral stimuli. Using eye-tracking, the specific dependent variable of 'break frequency' was defined, for measuring participants' ability to attend to the fixation target, whilst in the presence of distractor stimuli. This variable, we argue, allows a novel insight into AB and inhibitory processes. We speculate that AB is a process of distraction toward a stimulus which has become the focus of a bias in attention (e.g. Field & Cox, 2008). This AB process is speculated to operate outside of volition and attention will be oriented automatically toward an appropriate stimulus (e.g. Teunissen et al., 2012). As such a process is likely to be automatic (e.g. Tiffany, 1990), it would indicate loss of inhibitory control. Indeed, inhibitory control has long been associated with substance abuse (e.g. Ershe, et al., 2012). Clearly, the currently employed measures, such as the Stroop task and the dot-probe task, must embody some aspect of loss of inhibitory control, though, we argue, not to the same degree as the presently proposed task.

We suggest that break frequency is a (more) pure measure of loss of inhibitory control. We speculate that the break frequency variable would measure an inhibitory control component of AB, as task instructions were to exercise control over eye movement. Therefore any deviations from this requirement in the instructions, as a result of the stimuli presented, would indicate a failure in inhibition. We hypothesise that heavy drinking will be associated with increased 'break frequency'

2. Method

2.1 Participants

86 participants were recruited (31 males; 55 females) aged 18–49 years (m=20.88;sd=4.52) from the undergraduate populations within the psychology departments at Swansea University and London South Bank University. Participants were recruited using the psychology subject pools, and course credit was offered in return for participation. Reported alcohol use ranged from 0 to 51 units per week (m=14.53;sd=11.29). There were no inclusion/exclusion criteria for the study, however, normal/corrected vision was necessary in order to use the eye-tracking device. Participants were not informed of the relation of the study to excessive drinking. However, participants were fully debriefed, following the task.

Note, Stroop results are known to be affected by simple priming (e.g., Klein, 1964, reported that priming of Stroop words may increase interference). This is why we advertised for the study in a neutral way (that is, making no reference to the study's relation to alcohol use). Equally, we did not want to have participants respond to alcohol use questions after the AB task, since exposure to alcohol-related stimuli may have biased self-reports. Therefore, we included the alcohol use question before the AB task, but disguised within a larger questionnaire. The alcohol content of the study was only gradually revealed, as participants became aware of the alcohol-related stimuli, during the eye-tracking task. Participants were led to believe they were taking part in a task designed to look at eye movements and dyslexia.

As recruitment for the study did not specifically mention alcohol use, we expected that we would recruit a range of heavy and light drinkers (and this turned out to be the case). Note, in studies of AB it is common to recruit non-drinkers (or light drinkers) as well, as a control that the AB observed with e.g. heavy drinkers is exclusively (or primarily) due to heavy drinking and not, for example, due to the inherent salience of the alcohol-related stimuli.

2.2 Apparatus

An EyeLink Desktop 1000 eye-tracker (SR Research Ltd., Ontario, Canada) was used. Participants sat 55cm away from the monitor (60Hz). Their dominant eye was determined using the Miles test (Roth, Lora, and Heilman, 2002). Experimenter Builder software Version 1.4.128 B (SR Research Ltd., Ontario, Canada) was used to control the stimulus events during the eye-tracking task. ePrime software (Psychology Software Tools Inc., Pittsburgh, Pennsylvania) was used to control the presentation of the stimuli during the awareness task (which followed the eye-tracking one, see below).

2.3 Data Scoring and Response Definitions

It is possible to define several alternative, related variables, from our eye-tracking system, and we opted for using the one most clearly related to the issue of failures of inhibitory control, we were interested in. This was 'break frequency' – the number of times participants tried to look at the peripheral stimuli, so this variable is a direct measure of how distracting the peripheral stimuli were. In order to obtain a measure of how distracting alcohol distractor stimuli were, relative to neutral ones, the average break scores of neutral stimuli were subtracted from those for the corresponding alcohol ones. Thus, larger positive values indicate greater distractibility of alcohol distractor stimuli, relative to neutral ones.

2.4 Stimuli

Stimuli consisted of pictures from Hogarth, Dickinson, and Duka (2009). Each alcohol-related picture had a matched control picture. For example, a hand holding a pint of lager was matched with a hand holding an object, with broadly similar shape and colour, but not alcohol related (Figure 1). The alcohol-related distractor stimuli included pictures of lager or bitter beer, red and white wine, spirits including vodka, whisky, and gin, and alcopops. The neutral distractor stimuli were from a single thematic category, that of office equipment. They included pictures of books, phones, folders, etc. There were 16 pictures in each category and all pictures measured 105mm x 105mm. Distractor stimuli could be presented within any one of six equally-sized regions, which the computer monitor was notionally divided into (Figure 1). Finally, the fixation picture, participants were instructed to attend to, was as large as the alcohol-related or neutral distractor stimuli and designed to be visually salient (Figure 2).

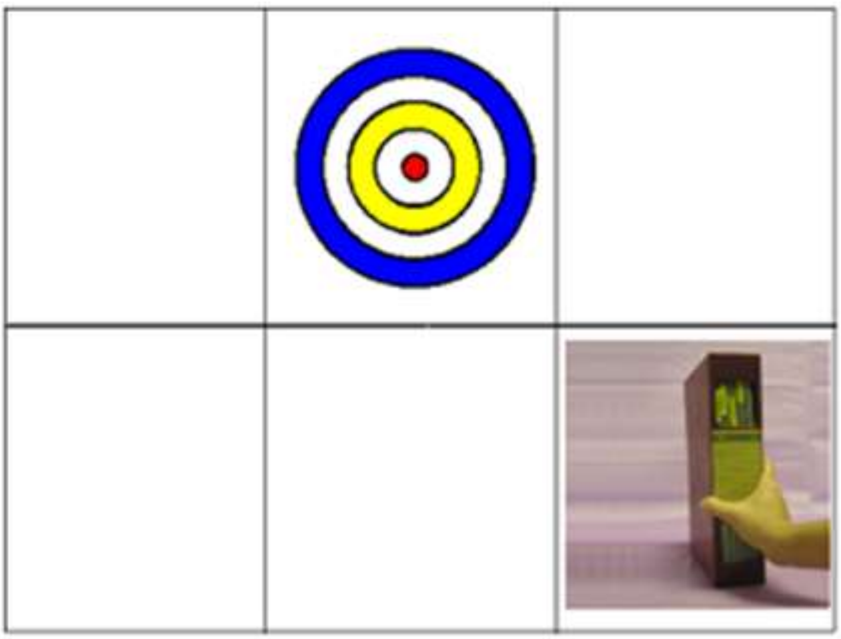

Figure 1. Example of fixation target and a distractor stimulus. No grid lines were present in the experiment; they are shown here to represent the six relevant sections of the screen.

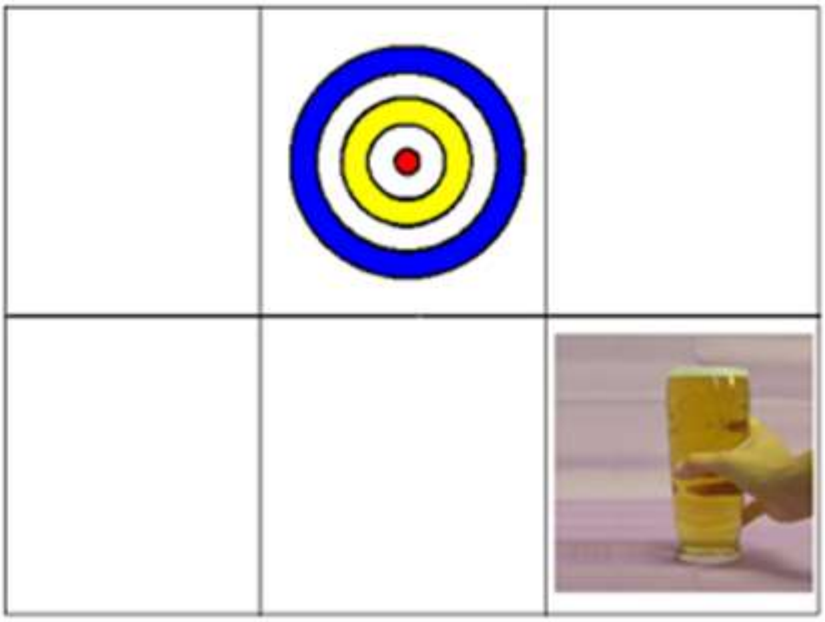

Figure 2. Example of an alcohol distractor stimulus, matched to the control one in Figure 1.

On each trial the fixation target appeared on the screen. Participants were instructed to always look at the fixation target. Once participants had attended to the fixation target for a fixed interval of one second, a distractor stimulus appeared (only one per trial). Following the presentation of the distractor stimulus, if the participant's gaze was to leave the fixation target boundary, then the distractor stimulus disappeared instantly. Therefore, participants were unable to fixate upon the distractor stimuli. For the distractor stimuli to reappear, participants need to fixate to the fixation target again for 10ms (i.e. less than one frame on a 60Hz monitor). The fixation target was displayed for five seconds in total, so the maximum duration for which a distractor stimulus could be displayed on the screen was 4 seconds. We chose a prolonged display time for the distractors, to make it harder for participants to ignore them. The dependent variable, break frequency, was the number of times participants tried to look at the distractor stimulus (see also Procedure).

Each alcohol-related distractor stimulus and its matched neutral stimulus were presented in separate trials, but each matched trial appeared at the same location on the screen. An alcohol distractor and its matched control distractor never appeared consecutively, neither was it the case that the fixation target appeared in the same location as a previous distractor stimulus. Therefore, the participant had to look at a different segment of the computer screen on each trial.

The distance between the distractor stimuli and the fixation target was manipulated, so that distances between the distractor stimulus and the fixation target could be 115mm, 165mm, 230mm, or 265mm. Distances were measured from the centre of the distractor stimuli to the centre of the fixation target. This manipulation was in place so as to make the task more interesting; for the purposes of statistical analyses, the distance variable was ignored. For each distance, a variety of alcohol drinks was displayed.

Participants completed a computer-based questionnaire, designed to look like a general health questionnaire, and included questions relating to dyslexia. Within this questionnaire, there was a key question related to typical weekly alcohol consumption. Participants were asked ‘How many alcohol units do you drink per week?’ and an alcohol unit calculator was provided which contained examples of alcoholic beverages and their alcohol unit content. The purpose of the questionnaire was disguised in this way, so as to minimise alcohol priming effects in the experimental task.

2.5 Procedure

Participants first completed the general health questionnaire and then performed the main experimental task, which involved being asked to continuously attend to the fixation target, whilst ignoring any distractor stimuli. Whilst participants were carrying out the task, an eye-tracker measured eye movements away from the fixation target. Recall, attention away from the fixation target threshold was measured and caused the distractor stimuli to disappear.

Because the distractor stimuli vanished as soon as participants directed their gaze towards the distractor stimuli, participants had very limited opportunity to process the distractor stimuli in detail. Therefore, following the eye-tracking task, participants completed an awareness task for the distractor stimuli (a computerised ePrime program). The stimuli in the awareness task were all the images employed in the eye-tracking task and some foils. The foils were 28 pictures from the database of Hogarth, Dickinson, and Duka (2009), which were not employed in the eye-tracking task. Therefore, there were 60 pictures in total, in the awareness task. In each trial, participants saw an image on a computer screen and were required to determine whether they had seen it previously and, if yes, how sure they were that they had seen it on a scale from 1 (not confident) to 7 (very confident). Each stimulus was shown until responses were made.

3. Results

We aimed to measure participants’ ability to inhibit their AB for alcohol distractors. The main independent variable was weekly alcohol unit consumption. The dependent variable, computed as the difference between breaking the threshold for the alcohol stimuli minus for the neutral stimuli, was the number of times a participant broke the fixation target threshold for the fixation target (see Table 1). There was a marginal significant difference for breaks between alcohol and neutral stimuli, $t(85)=-1.796; p=.076$.

Table 1. Descriptive statistics for the break frequency of alcohol stimuli, neutral stimuli, and the difference variable.

Variable	Mean (sd)
Alcohol-stimuli	1.10 (.39)
Neutral-stimuli	1.02 (.72)
Difference variable	.08 (.39)

We examined whether break frequency was associated with reported weekly alcohol unit consumption. A significant positive correlation was observed between the two variables, $r(84)=.225; p=.038$, consistent with the expectation that higher alcohol consumption is associated with a greater failure of inhibitory control, for alcohol-related stimuli, than for matched neutral ones. Alcohol consumption usually differs by gender, so it is important to control for this. Gender correlated with alcohol use, $r(84)=.328; p=.002$. But an interaction term for gender X break frequency was not found to correlate ($r(84)=.176; p=.105$). We considered all variables together in a regression model, to predict alcohol use, which was significant ($F(3,85)=6.154$; $p=.001$). The beta coefficient for break frequency was significantly different from 0 ($\beta=.304$, $t(85)=2.575; p=.012$) as was the case for the beta coefficient for the interaction term ($\beta=.262$, $t(85)=2.195; p=.031$). The beta coefficient for gender was only marginally significantly different from 0 ($\beta=.212$, $t(85)=1.952; p=.054$). Reported alcohol use is associated with break frequency for males ($r(29)=.366; p=.043$) differently from break frequency for females ($r(53)=.066; p=.631$). However, this result may just reflect the difference in average reported alcohol use in males ($m=26.80; sd=18.66$) and females ($m=12.73; sd=9.58$). In other words, the female participants in the sample were, relatively speaking, light drinkers, and this plausibly explains the lack of association between break frequency and alcohol use for female participants.

We carried out a preliminary reliability analysis, in which our sample was split into two groups and each participant in the first group was matched with a participant in the second group, in terms of alcohol use. Then, we correlated break frequency scores across the two groups. The highly significant correlation ($r(41)=.782; p<.0005$) provides a preliminary indication that our AB measure of break frequency scores is reliable. Finally, it was of interest to examine whether higher fixation counts would be associated with greater awareness, since the distracting images disappeared every time a participant tried to fixate on them. Note, one participant's results on the awareness task were unavailable due to a computer error. There were 60 images in the awareness task. The mean of participants' correct responses was 31.15 (SD=3.47), which is analogous to the 50% chance score would correspond to 30 correct responses. There was no significant correlation between break frequency and awareness (computed as the percentage of correct responses in the awareness task), $r(83)=-.006; p=.957$. Thus, there was no evidence that participants could recognise the distractor stimuli, against distractors, even though the AB results clearly indicated sensitivity to the content of the stimuli (alcohol vs. neutral). Another way which might reveal explicit knowledge of the stimuli is through the use of the so-called ‘zero order’ correlation criterion (Dienes et al., 1995) involving percentage correct and confidence. But, the correlation was low and not significant, $r(83)=.056; p=.612$. These results further indicate that processing of the distractor stimuli can be said to be implicit, an interesting finding indicating how even implicit (or at the very least impoverished) representations can trigger ABs.

4. Discussion

We presented a novel experimental task for the measurement of failures of inhibitory control, in relation to AB. The task is based on a gaze contingent eye-tracking task. All traditional tasks measuring AB with eye-tracking techniques rely on the idea that a higher degree of AB would be associated with a greater preference of an alcohol-related stimulus, relative to a neutral stimulus. Such AB concern the extent to which processing of alcohol-related information is prioritised and there is no doubt that this is a key aspect of what AB are (Field, 2010; Hogarth *et al.*, 2009). With the present research, we explored the possibility of an inhibitory control component of AB, reflecting whether processing of alcohol-related (relative to neutral) information is compulsory. Exactly how distracting is an alcohol-related stimulus for an alcohol abuser? Such a perspective to AB links well with corresponding theory regarding how alcohol abuse may undermine inhibitory processes, in relation to alcohol use (cf. Field & Cox, 2004; Wiers & Stacy, 2010).

Note that in making the distinction between preference and loss of inhibitory control, we are fully aware that this is not a black and white distinction. Clearly, a task like the Stroop task must involve some aspect of loss of inhibitory control too and, likewise, our eye-tracking method must involve an aspect of attentional orientation. Our point, rather, is that our eye-tracking method reveals ABs primarily due to loss of inhibitory control, in the simple sense that the task is such that participants could very easily ignore the alcohol-related stimuli (these stimuli are not meant to be what the participant should be attending to and, moreover, they are not even ‘close’ to the intended target). It is this aspect of the reported method that differentiates from existing proposals and, we think, warrants an interpretation of any ABs as primarily due to loss of inhibitory control.

To summarise our experimental task, participants had to focus on a simple fixation target and ignore any presented distractor stimuli. Heavy drinkers produced more fixations to the alcohol distractor stimuli than the neutral ones, relative to light drinkers. From the descriptive statistics, it is clear that overall distraction for neutral stimuli and alcohol stimuli was of a similar level. This, combined with the significant correlation between alcohol units and difference score, suggests that most participants were distracted to some degree by the stimuli. However, those who reported higher alcohol-use were consistently distracted by the alcohol-related stimuli more so than for the neutral stimuli. These results provide novel evidence for the idea that alcohol-related information can have a distracting influence for heavy drinkers, more so than alternative AB tasks (as argued above). The results also empirically support the proposal of Tiffany (1990), who suggested that substance abuse reflects a 'loss of control'. Likewise, Field and Cox (2008) argued that poor inhibitory control may influence craving, substance seeking, and subsequent AB, so that poor inhibitory control (as demonstrated in the present study) is an important component of substance abuse.

It was also observed that gender was associated with the break frequency variable and alcohol use. It appears that the male participants were distracted by the alcohol stimuli more than the female participants. However, the male participants in our sample reported a higher average alcohol unit count than the female ones. Therefore, it is likely that any effects of gender on break frequency are possibly the result of alcohol use differences. Clearly more research is needed to explore whether there may be differences in break frequency as a function of gender, though given existing results with other AB tasks, this possibility seems unlikely.

The proposed paradigm is similar to antisaccade tasks. However, we think the current task affords procedural advantages (e.g., the instructions are straightforward for participants to follow) and conceptual advantages (it is straightforward to extract a suitable dependent variable from the task, to measure failures of inhibitory control). Participants were just instructed to keep their gaze within the target threshold to complete the task and a visually salient target would appear as indicated. It can be trivially assumed that there were adequate incentives to follow the instructions, so that saccades away from the target reflected some loss of inhibitory control and so a corresponding AB.

An interesting point relates to our results regarding awareness of the distractor stimuli. The observed lack of awareness of the distractor stimuli indicates that, despite any corresponding AB, processing of these stimuli was implicit. It is possible that this implicitness arises simply from the promptness with which the distractor stimuli disappeared, when they were attended to. Future extensions could usefully manipulate the disappearing time of the distractor stimuli. Another possibility is that, even with longer exposure times, processing of the alcohol stimuli will continue to be implicit, perhaps indicating a conceptual (gist-like; cf. Reyna & Brainerd, 1995) processing.

It would appear that the new task is able to measure an aspect of AB and inhibition which may be distinct from other measures. Instead of measuring preferential processing of stimuli, the current task is able to measure an inability to not preferentially process stimuli. This method for measuring AB may be advantageous as it may be more sensitive to a 'loss of control' substance seeking behaviour (see Tiffany, 1990). It may also reflect implicit substance 'wanting' rather than 'liking' (see Robinson & Berridge, 1993). Substance 'liking' could represent preferential processing of stimuli, which current AB tasks measure. It may be that 'wanting', which may occur in the absence of 'liking', represents a different pattern of AB which the current task can measure due to the decreased awareness of the stimuli.

This would suggest that when a participant is unable to inhibit their AB, yet there is an absence of awareness of the stimuli content, then substance seeking is operating outside of awareness and is indicative of a loss of control. An important direction for future research concerns comparing the current measure with established measures of AB, such as the Stroop task and the dot-probe task. There are two challenges in doing so. First, to assess the issue of task inter-relatedness, a within participants design is needed. However, it is very difficult to implement such designs, since there are very tricky priming influences from task to task. Second, in actual fact, there are very few comparative studies even for the established measures. In one of the few studies we are aware of, Pothos, Tapper, and Calitri (2009) reported very poor correlations amongst AB measures related to eating behaviour. Thus, there is a lack of understanding regarding inter-relatedness between existing AB measure already, without taking into account novel (and less well understood) tasks.

A related direction for future research concerns further exploring the reliability and validity of the task. Regarding validity, exploring the break frequency measure in conjunction with other attentional bias tasks leads us to the problems just mentioned, namely that there are significant challenges in within-participant designs involving several AB tasks. However, the high correlation between the break frequency scores and alcohol use is an encouraging test of task validity. In the future, it would certainly be important to include more detailed and extensive measures of alcohol use and, in particular, measures of alcohol dependency (in this study, we cannot discriminate between heavy drinking and alcohol dependency). Note that, given the demographics of our sample (university undergraduates, mean age of 20.9 years), we think it is unlikely that we had alcohol-dependent participants, however, of course, this is an issue which should be directly controlled for in the future. Regarding reliability, researchers have been recognizing this as an important issue in research in ABs, with the reliability of some AB tasks being questioned (Ataya et al., 2012). Our preliminary reliability analysis is certainly encouraging, but, in the future, we would like to employ procedures which will allow more thorough reliability analyses.

Finally, perhaps the most significant extension of the present work concerns an examination of the predictive role of AB measured with break frequency, in relation to changes in alcohol use. Such predictive results in alcohol abuse (Cox *et al.*, 2002; Cox, Pothos, & Hosier, 2007) and appetitive behaviour in general (Calitri *et al.*, 2010) have been cornerstones in motivating an understanding of AB as having a *causal* role in the corresponding behaviour and related theoretical developments. Will failures of inhibitory control for alcohol-related stimuli produce similar predictive results? This is an exciting challenge for future work.

References

Ansari TL, Derakshan N, & Richards A (2008). Effects of anxiety on task switching: Evidence from the mixed antisaccade task. Cogn Affect Behav Neurosci, 8(3), 229-238.

Ataya AF, Adams S, Mullings E, Cooper RM, Attwood AS, Munafò MR. (2012) Internal reliability of measures of substance-related cognitive bias. Drug Alcohol Depend. 1;121(1-2):148-51.

Calitri R, Pothos EM, Tapper K, Brunstrom JM, & Rogers PJ (2010). Cognitive Biases To Healthy And Unhealthy Food Words Predict Change In BMI. Obesity, 18, 2282-2287.

Cox WM, & Klinger E (Eds.) (2004). Handbook of motivational counseling: Concepts, approaches, and assessment. John Wiley & Sons.

Cox WM, Fadardi JS, & Pothos EM (2006). The Addiction-Stroop Test: Theoretical Considerations And Procedural Recommendations. Psychol Bull, 132, 443-476.

Cox WM, Hogan LM, Kristian MR, & Race JH (2002). Alcohol Attentional Bias As A Predictor Of Alcohol Abusers' Treatment Outcome. Drug Alcohol Depend, 68(3), 237-243.

Cox WM, Pothos EM, & Hosier SG (2007). Cognitive-Motivational Predictors Of Excessive Drinkers' Success In Changing. Psychopharmacology, 192(4), 499-510.

Dienes Z, Altmann G, Kwan L, & Goode A (1995) Unconscious Knowledge Of Artificial Grammars Is Applied Strategically. J Exp Psychol Learn Mem Cogn 21, 1322-1338

Ersche KD, Jones PS, Williams GB, Turton AJ, Robbins TW, & Bullmore ET (2012). Abnormal brain structure implicated in stimulant drug addiction. Science, 335(6068), 601-604.

Field M (2010). Can't Take My Eyes Off Of You. Psychologist 23(8), 636-639.

Field M, & Cox WM (2008). Attentional bias in addictive behaviors: a review of its development, causes, and consequences. Drug Alcohol Depend,97(1), 1-20.

Field M, & Eastwood B (2005). Experimental Manipulation Of Attentional Bias Increases The Motivation To Drink Alcohol. Psychopharmacology, 183(3), 350-357.

Field M, Christiansen P, Cole J, & Goudie A (2007). Delay discounting and the alcohol Stroop in heavy drinking adolescents. Addiction, 102(4), 579-586.

Fleming KA, & Bartholow BD (2014). Alcohol cues, approach bias, and inhibitory control: Applying a dual process model of addiction to alcohol sensitivity. Psychol Addict Behav, 28(1), 85.

Garner M, Attwood A, Baldwin DS, James A, & Munafò MR (2011). Inhalation of 7.5% Carbon Dioxide Increases Threat Processing in Humans. Neuropsychopharmacol, 36(8), 1557-1562.

Garner M, Baldwin DS, Bradley BP, & Mogg K. (2009). Impaired identification of fearful faces in Generalised Social Phobia. J Affect Disord, 115(3), 460-465.

Hogarth L, Dickinson A, & Duka T (2009). Detection Versus Sustained Attention To Drug Cues Have Dissociable Roles In Mediating Drug Seeking Behavior. Exp Clin Psychopharmacol, 17(1), 21.

Jones A, & Field M (2013). The effects of cue-specific inhibition training on alcohol consumption in heavy social drinkers. Exp Clin Psychopharmacol, 21(1), 8-16.

Jones BT & Schulze D (2000). Alcohol-Related Words Of Positive Affect Are More Accessible In Social Drinkers' Memory Than Other Words When Sip-Primed By Alcohol. Addict Res 8, 221-232

Klein GS. (1964). Semantic power measured through the interference of words with color-naming. Am J Psychol, 576-588.

Macleod C, Mathews A, & Tata P (1986). Attentional Bias In Emotional Disorders. J Abnorm Psychol, 95, 15-20.

Noël X, Van der Linden M, Brevers D, Campanella S, Verbanck P, Hanak C, . . . Verbruggen F (2013). Separating intentional inhibition of prepotent responses and resistance to proactive interference in alcohol-dependent individuals. Drug Alcohol Depend, 128(3), 200-205.

Noël X, Van der Linden M, d'Acremont M, Colmant M, Hanak C, Pelc I, ... & Bechara A (2005). Cognitive biases toward alcohol-related words and executive deficits in polysubstance abusers with alcoholism. Addiction, 100(9), 1302-1309

Palfai TP & Ostafin BD (2003). Alcohol-Related Motivational Tendencies In Hazardous Drinkers: Assessing Implicit Response Tendencies Using The Modified IAT. Behav Res Ther, 41, 1149-1162.

Posner MI, Cohen Y (1984). Components Of Visual Orienting. In Attention and Performance Vol. X (Bouma H, Bouwhuis D, Eds), Pp. 531–556, Erlbaum

Pothos EM, Tapper K, & Calitri R (2009). Cognitive and behavioral correlates of BMI among male and female undergraduate students. Appetite,52(3), 797-800.

Rafal R, Davies J, & Lauder J (2006). Inhibitory Tagging At Subsequently Fixated Locations: Generation Of "Inhibition Of Return" Without Saccade Inhibition. Vis Cogn 13, 308-323

Rather BC, Goldman MS, Roehrich L, & Brannick M (1992). Empirical Modelling Of An Alcohol Expectancy Memory Network Using Multidimensional Scaling. J Abnorm Psychol 101, 173-183

Reyna VF & Brainerd CJ (1995). Fuzzy-trace theory: an interim synthesis. Learn Individ Differ, 7, 1-75.

Robbins SJ, & Ehrman RN (2004). The role of attentional bias in substance abuse. Behav Cogn Neurosci Rev, 3(4), 243-260.

Roberts RJ, Hager LD, & Heron C (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. J Exp Psychol Gen, 123(4), 374.

Robinson TE & Berridge KC (1993). The Neural Basis Of Craving: An Incentive-Sensitization Theory Of Addiction. Brain Res Rev, 18, 247-291.

Roth HL, Lora AN, & Heilman KM (2002). Effects Of Monocular Viewing And Eye Dominance On Spatial Attention. Brain 125, 2023–2035

Schoenmakers TM, De Bruin M, Lux IF, Goertz AG, Van Kerkhof DH, & Wiers RW (2010). Clinical Effectiveness Of Attentional Bias Modification Training In Abstinent Alcoholic Patients. Drug Alcohol Depend, 109(1), 30-36.

Sharma D, Albery IP, & Cook C (2001). Selective attentional bias to alcohol related stimuli in problem drinkers and non-problem drinkers. Addiction,96(2), 285-295.

Stacy AW (1997). Memory Activation And Expectancy As Prospective Predictors Of Alcohol And Marijuana Use. J Abnorm Psychol, 106, 61-73.

Teunissen HA, Spijkerman R, Schoenmakers TM, Vohs KD, & Engels RC (2012). The Effect of Self-Control on Attentional Bias for Alcohol Cues in Male Heavy Drinkers1. J Appl Soc Psychol, 42(3), 776-792.

Tiffany ST (1990). A Cognitive Model Of Drug Urges And Drug-Use Behavior: Role Of Automatic And Nonautomatic Processes. Psychol Rev, 97, 147-168.

Waters AJ, & Feyerabend C (2000). Determinants And Effects Of Attentional Bias In Smokers. Psychol Addict Behav, 14, 111-120

Weafer J, & Fillmore M (2012). Alcohol-Related Stimuli Reduce Inhibitory Control Of Behavior In Drinkers. Psychopharmacol: 1-10

Wiers RW & Stacy AW. (2010). Are Alcohol Expectancies Associations? Comment On Moss And Albery (2009). Psychol Bull 136, 12-16

Wiers RW, Bartholow BD, Van Den Wildenberg E, Thush C, Engels RCME, Sher KJ, Grenard J, Ames SL, Stacy AW (2007). Automatic And Controlled Processes And The Development Of Addictive Behaviours In Adolescents: A Review And A Model. Pharmacol Biochem Behav. 86, 263–283