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Visual and auditory contextual cues differentially influence alcohol-related inhibitory control

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Resumen

Introducción: Con el objetivo de crear un entorno de evaluación más ajustado a la realidad, en este estudio se expuso a los participantes a estímulos visuales y auditivos relacionados con el alcohol para evaluar su impacto en el control inhibitorio relacionado con el alcohol. Además, se examinó si las diferencias individuales en el consumo de alcohol y el rasgo autorregulación predecían el rendimiento del control inhibitorio. Método: Veinticinco estudiantes universitarios del Reino Unido (edad media = 23,08 años; DT = 8,26) llevaron a cabo una tarea anti-sacádica de seguimiento ocular, en la que se les pedía que miraran hacia (pro), o directamente en la dirección contraria (anti), estímulos visuales tanto relacionados con el alcohol como neutros. Además, en el 50% de los ensayos se reprodujeron estímulos auditivos breves relacionados con el alcohol (sonido de bar), y las respuestas se compararon con las que se producían cuando no había sonidos. Resultados: Los resultados indican que los participantes dirigieron más movimientos sacádicos incorrectos hacia los estímulos visuales relacionados con el alcohol en los ensayos anti-sacádicos, y que respondieron más rápido al alcohol en los ensayos pro-sacádicos. Los estímulos auditivos relacionados con el alcohol redujeron la latencia de respuesta tanto para los ensayos pro como anti-sacádicos, y redujeron la tasa de errores anti-sacádicos en los estímulos relacionados con el alcohol. Sin embargo, estos efectos se eliminaron al controlar el rasgo autorregulación y el consumo problemático de alcohol. Conclusiones: Estos resultados sugieren que los estímulos visuales relacionados con el alcohol pueden estar asociados con una reducción del control inhibitorio, lo cual se pone de manifiesto en un aumento en los errores y en unas latencias de respuesta más rápidas. Sin embargo, la presentación de estímulos auditivos relacionados con el alcohol parece aumentar la precisión en la tarea. Se propone que los estímulos auditivos pueden recontextualizar los estímulos visuales en un contexto más familiar que reduce su prominencia y disminuye su capacidad de atención.

Palabras-clave: consumo de alcohol, control inhibitorio, efectos contextuales, anti-sacádico, autorregulación

Abstract

Introduction: Representing a more immersive testing environment, the current study exposed individuals to both alcohol-related visual and auditory cues to assess their respective impact on alcohol-related inhibitory control. It examined further whether individual variation in alcohol consumption and trait effortful control may predict inhibitory control performance. Method: Twenty-five U.K. university students (*M*age = 23.08, *SD* = 8.26) completed an anti-saccade eye-tracking task and were instructed to look towards (pro) or directly away (anti) from alcohol-related and neutral visual stimuli. Short alcohol-related sound cues (bar audio) were played on 50% of trials and were compared with responses where no sounds were played. Results: Findings indicate that participants launched more incorrect saccades towards alcohol-related visual stimuli on anti-saccade trials, and responded quicker to alcohol on pro-saccade trials. Alcohol-related audio cues reduced latencies for both pro- and anti-saccade trials and reduced anti-saccade error rates to alcohol-related visual stimuli. Controlling for trait effortful control and problem alcohol consumption removed these effects. Conclusion: These findings suggest that alcohol-related visual cues may be associated with reduced inhibitory control, evidenced by increased errors and faster response latencies. The presentation of alcohol-related auditory cues, however, appears to enhance performance accuracy. It is postulated that auditory cues may re-contextualise visual stimuli into a more familiar setting that reduces their saliency and lessens their attentional pull.

Key words: Alcohol consumption, inhibitory control, context effects, anti-saccade, effortful control

Exposure to alcohol-related stimuli, environments, and paraphernalia has been shown to impair inhibitory control in both clinical and non-clinical populations (e.g. Field, Wiers, Christiansen, Fillmore, & Verster, 2010; Fleming & Bartholow, 2014; Kreusch, Vilenne, & Quertemont, 2016; Papachristou et al., 2013). Individuals with low sensitivity to the acute effects of alcohol exhibit automatic approach biases towards alcohol-related visual stimuli, and experience more conflict when attempting to inhibit alcohol-cued compared to non-alcohol cued responses (Fleming & Bartholow, 2014). Non-problem drinkers also appear to show disinhibition towards alcohol-related visual stimuli, responding with significantly more errors and quicker reaction times towards alcohol-related stimuli on the Cued Go/No-Go task (Kreusch et al., 2013) and anti-saccade task (Jones & Field, 2015; King & Byers, 2004; Laude & Fillmore, 2015; McAteer, 2015). This heightened approach bias towards alcohol-related stimuli is theorised to reflect the salience of such cues to individuals who consume alcohol (Grant & Macdonald, 2005; Rose & Duka, 2008).

Through the process of conditioning, alcohol-related cues are associated with the perceived positive expectancies of drinking and become increasingly attractive (c.f., Jones, Hogarth, Christiansen, Rose, Martinovic, & Field, 2012; Tuenissen, Spijkerman, Schoenmakers, Vohs, & Engels, 2012). Resultantly, attention is drawn to alcohol-related cues (Tuenissen et al., 2012) which, in turn, may lead to an increase in craving (Manchery et al., 2017) and consumption (e.g., Weafer & Fillmore, 2013). Inhibition is proposed to control the strength of alcohol-related attentional biases (Field & Cox 2008) by moderating processes such as automatic approach tendencies (e.g., Wiers et al., 2007), as well as implicit associations (e.g., Houben & Wiers, 2008). For this reason, inhibitory control is theorised to be an important driver of consumption behaviours (Cooney, Gillespie, Baker, & Kaplan, 1987; Nees, Diener, Smolka, & Flor, 2012). Indeed, it has been found that both automatic

approach tendencies and impulsivity (decision-making and inhibitory control) predict alcohol consumption behaviour (Christiansen et al., 2012).

Research has also found that trait effortful control and self-reported consumption are important in the study of inhibitory control and attentional bias towards alcohol-related cues. For example, McAteer and colleagues (2015) revealed that alcohol use was significantly correlated with fixation times to alcohol stimuli. Specifically, adolescent social drinkers spent more time fixating on alcoholic stimuli compared to abstainers. These results were interpreted to suggest that alcohol-related attentional bias is driven by experiences with, and positive expectancies, surrounding alcohol, which may have implications of interventions seeking to reduce consumption (ibid). Indeed, research consistently reveals that inhibitory control and attentional bias vary across populations with differing levels of alcohol consumption (e.g., Goudriaan, Oosterlaan, De Beurs & van den Brink, 2006; Murphy & Garavan, 2011; Nederkoorn, Baltus, Guerrieri & Wiers, 2009; Qureshi et al., 2017), with more problematic alcohol consumption related to heightened approach biases towards alcohol-related stimuli (Albery, Sharma, Noyce, Frings, & Moss, 2015; Field, Marhe, & Franken, 2014; McAteer, Curran, & Hanna, 2015; Roberts, Miller, Weafer, & Fillmore, 2014).

Moreover, there is some evidence supporting a relationship between elevated trait impulsivity and increased alcohol consumption and problem drinking (Gunnersson, et al., 2008; McAdams & Donnellan, 2008; Von Diemen et al., 2008). Indeed, higher trait self-control – the ability to override impulsive responding – enables individuals to disengage attention from alcoholic cues (Teunissen et al., 2012; Qureshi et al., 2017). More recent research utilising behavioural measures has suggested, however, that impulsivity fluctuates within the individual and is susceptible to the influences of external factors (e.g., context).

For example, Qureshi et al. (2017) found that higher effortful control facilitates performance on an alcohol-related Go/No-Go Task. Taken together, these findings suggest that self-reported alcohol consumption and trait effortful control also warrant careful consideration during the assessment of how alcohol-related cues may impact inhibition.

Stein and colleagues (2000) note that research has focused on the way in which alcohol-related visual, auditory and tactile cues shape alcohol-related thoughts and behaviours. Indeed, previous studies have provided plentiful evidence for the impact of visual alcohol-related stimuli on inhibitory control mechanisms (e.g., Kreusch et al., 2013; Weafer & Fillmore, 2012), yet relatively less research has examined the impact of alcohol-related auditory stimuli on these processes. As an exception, one study has shown that alcohol-related visual cues impede processing of simultaneously presented auditory signals on a multisensory perception task (Monem & Fillmore, 2016). Other research beyond the focus of substance misuse asserts that the impact of auditory cues on visual attention may be contingent upon their relevance to the task at hand (Leiva, Parmentier, Elchlepp, & Verbruggen, 2015). Specifically, Leiva et al. (2015) found that inhibitory control performance was facilitated when participants' perceived auditory cues to be relevant to visually presented targets (i.e., a tone which indicated to participants that they should respond). Conversely, novel, unexpected sounds (i.e., environmental sounds) impaired performance because participants could not identify their relation to the task requirements[1]. Given that there is a semantic linkage between alcohol-related sounds[2] (i.e., bar-related sounds, such as the opening of beer bottles) and the presentation of alcohol-related visual

[1]Here, it may be postulated that the processing of a novel stimuli divides attention, reducing the resources allocated to inhibitory control, thus impairing performance.
[2]According to relational frame theory, related concepts are stored in memory and exposure to one concept can lead to a process of spreading activation, where related constructs are also activated. There are therefore theoretical grounds to propose a semantic link between alcohol-related sights and sounds, with the processes evident upon exposure to alcohol-related visuals also elicited by other sensory cues (Riecke, Schulte-Pelkum, Caniard, & Bülthoff, 2005).

stimuli, we therefore speculate that inhibitory control performance may be facilitated, rather than impaired, under such conditions.

Building upon these early findings, the current research examined the influence of contextually relevant alcohol-related visual (e.g., a bottle of liquor) and auditory cues (e.g., opening of alcohol) on inhibitory control mechanisms. Employing the anti-saccade eye-tracking task (a direct measure of inhibition; Munoz & Everling, 2004), participants were instructed to fixate on a central point and launch eye movements either towards (pro) or away (anti) from a peripherally placed alcohol-related or neutral target. Within this task, auditory cues that were semantically related to alcohol were presented during 50% of the trials, prior to the alcohol-related visual targets. In line with previous research (Jones & Field, 2015; McAteer, 2015), it was predicted that participants would respond faster to alcohol-related relative to neutral visual stimuli on pro-saccade trials. It was also predicted that they would launch a greater proportion of incorrect saccades towards alcohol-related stimuli during anti-saccade trials, demonstrating enhanced attentional bias. Moreover, it was expected that participants would be more accurate and quicker to respond to alcohol-related visual stimuli on pro-saccade trials when they were exposed to short bar-related auditory cues (as per Leiva et al., 2015). However, during anti-saccade trials, we predicted that alcohol-related auditory cues would interfere with goal-directed performance and impair inhibitory control towards visual alcohol-related stimuli (c.f., Monem & Fillmore, 2016). This was underpinned by the rationale that hearing alcohol-related sound (i.e., audio from a bar environment) should make alcohol-related cues more salient to the individual, attracting their attention.

As a second aim, we also investigated whether individual differences in alcohol consumption and trait effortful control could explain the influence that alcohol-related visual and auditory stimuli exert on inhibitory control. We predicted that participants with lower trait effortful control would launch more incorrect saccades and have faster response latencies

to both types of visual stimuli, and within those participants, individuals with higher level of problematic alcohol consumption would show greater response impairment to alcohol-related stimuli (specifically when alcohol-related auditory cues and visual stimuli were paired).

Method

Participants

This experimental study follows the international agreements on human experimentation and was approved by the ethics committee at Edge Hill University (UK). Twenty-five participants (15 female, *M*age = 23.08, *SD* = 8.26; age range 18-53) were recruited via opportunity sampling. The minimum number of participants was determined by an a-priori power analysis, based on pilot studies, and indicated that a minimum sample size of 12 participants was required to detect a predicted effect size of $\eta_p^2 = .17$ with 80% power. In order to ensure sufficient statistical power, this recommended sample size was doubled and25 participants were recruited. This sample size and gender ratio is consistent with that reported in previous research (Monem & Fillmore, 2016, *n* = 25, *n* = 13 females; Leiva et al., 2013, *n* = 20, *n* = 15 females; Vorstius, Radach, Lang, & Riccardi, 2008; *n* = 24, *n* = 12 females). Participants were required to be over the legal age of drinking to take part (18 years old in the U.K.) and reported no visual acuity or auditory deficits.

Measures

Alcohol Consumption. The Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) was used to assess alcohol consumption and drinking behaviours. Participants respond to this 10-item questionnaire on a Likert response scale anchored between 0 (Never) and 4 (4 or more times). Responses to this questionnaire showed excellent internal consistency, Cronbach's *a* = 0.80, with a mean of 6.26 (*SD* = 3.82).

Effortful Control. The effortful control sub-section of the Adult Temperament Questionnaire (ATQ; Rothbart et al., 2000) was used to measure trait effortful control. This 35-item sub-scale includes three sub-components of attentional control (capacity to voluntarily focus as well as shift attention), inhibitory control (capacity to suppress inappropriate approach behavior), and activation control (capacity to perform activities that one would rather avoid). Participants responded to questions on a Likert scale anchored between 1 (Extremely untrue of you) and 7 (extremely true of you). Responses to this questionnaire also showed excellent internal consistency, $a = 0.90$, with a mean of 50.97 (*SD* = 10.20).

Anti-saccade task. Participants completed an anti-saccade task to measure their inhibitory control performance. Throughout this task, participants' eye-movements were recorded using a video-based pupil-tracking system (EyeLink 1000; SR Research Ltd), and their heads were stabilised by a chin rest situated 57cm from the computer.

Visual Stimuli. For the alcohol-related visual stimulus, a bottle of unbranded liqueur was used, whilst the neutral stimulus was a green rectangle, matched for size and luminosity. Given the size of the stimuli and the short duration of presentation, the study needed to use stimuli that were recognisably alcohol related and non-alcohol related. Previous research has revealed that the use of alcoholic and non-alcoholic appetitive stimuli (e.g. alcoholic versus soft drinks – Cavanagh & Obasi, 2015) or alcoholic versus neutral stimuli (Kreusch et al., 2013) has yielded mixed results, so the decision was made to use explicitly alcohol-related and non-alcohol related visual cues.

Auditory Stimuli. A series of pilot studies were conducted to establish the optimum audio cues (See Supporting Information File 1). Participants heard bar-related cues of short

duration (48 kHz), which were presented randomly on 50% of trials[3]. On the remaining 50% of trials, no sound was heard. Auditory cues were presented randomly after the onset of a fixation cross for the remaining duration of the trial (see Figure 1).

Procedure

Participants were asked to refrain from consuming alcohol 12 hours before taking part in the study. On arrival, they first completed the anti-saccade task and then the AUDIT and ATQ to avoid alcohol-related priming of the questionnaire content (in line with McAteer et al., 2015). Participants sat in a quiet room in front of a computer screen and were asked to wear headphones. Eye movements were validated using a nine-point calibration system.

Within both pro- and anti-saccade trials, participants were instructed to fixate on a black cross, presented on a white background. This was followed by an auditory cue with a stimulus onset asynchrony of 800 or 1000ms after fixation cross presentation (randomised) on 50% of trials. This fixation point then changed to a coloured dot after 1500ms,informing the participant to perform an anti- (red) or pro-saccade (blue). Alcohol-related (a bottle of unbranded liquor) or neutral stimuli (a green rectangle) were then presented randomly on either the left or right side of the computer screen for 1500 ms. During pro-saccade trails, participants were required to look directly at the target as quickly and accurately as possible. During anti-saccade trials, participants were instructed to look directly away from the target, to its mirror position. The auditory cue lasted until the end of the trial and the inter-trial interval was 1500 ms. Figure 1 provides an overview of the trial procedure.

The experiment was organised into eight blocks of four anti-saccade and four pro-saccade trials, and block order (pro or anti) was randomised for each participant. There were

[3] After completing the task, participants were asked what they thought the auditory cues represented. All stated that the cues were bar-related.

a total of 224 trials, with 28 trials per block. The alcohol-related and neutral visual stimuli order and position were randomised within blocks, and were balanced equally within blocks and overall. The first eight trials in each block were treated as practice trials and removed from the final analyses (as per Umiltà & Moscovitch, 1994).

[INSERT FIGURE 1 HERE]

Data Analysis

Saccades with initial latencies of 80-600ms and amplitudes more than 2° were included (c.f. Kanjee, Yücel, Steinbach, González & Gupta, 2012), resulting in 3798 valid trials (91.3%), a similar proportion to other saccade experiments (e.g. Vorstius, Radach, Lang & Riccardi, 2008). The initial saccades that met these parameters and were also classified as 'full' saccades towards (pro) or away (anti) from the stimuli were included in the final analyses. This was achieved using 'barriers' set at $x = 412$ for the left of the screen and $x = 612$ for the right of the screen. Specifically, saccade end-points were included if they were beyond the appropriate barrier (for example, a pro-saccade trial to the right-hand side of the screen would need to exceed 612), and met the latency parameters. For error rates, the barrier was used to assess if saccades ended past the barrier on the incorrect side.

A series of two-way repeated measures Analysis of Variance tests (ANOVA) were conducted for response latencies and error rates on anti- and pro-saccade trials to examine the effect of visual stimuli (alcohol-related or neutral images) and auditory cue type (alcohol-related and none). Analyses of Covariance (ANCOVA), including follow-up simple main effect analyses, were then conducted to elucidate any moderating role of alcohol consumption (AUDIT) and trait effortful control (ATQ; in accordance with Judd, Kenny, & McClelland, 2001).

Results

Saccadic Latencies

Pro-saccade trials. There was a significant main effect of visual stimuli, with faster latencies to alcohol stimuli (M = 232.59, SD = 46.77) compared to neutral stimuli (M = 249.18, SD = 50.50), $F(1, 24) = 9.75$, $p < .01$, $\eta_p^2 = .29$. There was also a significant main effect of auditory cue type, with bar-related sound cues facilitating responses (M = 229.96, SD = 45.23) compared to no sound cue (M = 251.82, SD = 52.18) across both visual stimuli types, $F(1, 24) = 15.53$, $p < .01$, $\eta_p^2 = .39$. There was no significant interaction between visual and auditory stimuli, $p > .05$. Adding AUDIT and trait effortful control as covariates resulted in no significant main effects or interactions (all p's > .19).

Anti-saccade trials. There was no significant main effect of visual stimuli (p = .46), and no interaction between visual stimuli and auditory cue type (p = .64). A significant main effect of auditory cue type indicated that bar-related cues facilitated response latencies (M = 280.57, SD = 53.65) compared to when there was no cue (M = 319.37, SD = 53.00) for both visual stimuli types, $F(1, 24) = 33.18$, $p < .01$, $\eta_p^2 = .58$. Adding AUDIT and trait effortful control as covariates resulted in no significant main effects or interactions (all p's > .06). Latencies by saccade type, visual stimuli and auditory cue type are shown in Table 1.

[INSERT TABLE 1 HERE]

Error rate (anti-saccade only)

There was a significant main effect of visual stimuli with more errors to alcohol stimuli (M = 0.19, SD = 0.16) relative to neutral stimuli (M = 0.13, SD = 0.11), $F(1, 24) = 10.44$, $p < .01$, $\eta_p^2 = .30$. There was also a significant main effect of auditory cue type with participants making fewer errors when they were cued with bar-related sounds (M = 0.12, SD = 0.11)

compared to no sound (M = 0.20, SD = 0.15), $F(1, 24) = 14.45$, $p < .01$, $\eta_p^2 = .38$. There was a significant interaction between visual stimuli and auditory cue type, $F(1, 24) = 20.48$, $p < .01$, $\eta_p^2 = .46$. Simple main effects showed that error rates were significantly higher for alcohol-related visual stimuli compared to neutral stimuli when there was no auditory cue ($p < .01$); however there was no difference in error rates between the visual stimuli when hearing bar-related cues ($p = .57$). Error rates were significantly lower for alcohol-related visual stimuli when there was a bar-related cue compared to no cue ($p < .01$), yet there was no significant difference between auditory cue type for neutral visual stimuli ($p = .77$). See Figure 2.

Adding AUDIT and trait effortful control as covariates resulted in a significant main effect of trait effortful control with overall error rates reducing as trait effortful control increased, $F(1, 20) = 6.55$, $p < .05$, $\eta_p^2 = .25$. There was no relationship with AUDIT, $p > .05$. There was also a significant interaction between visual stimuli and auditory cue type, $F(1, 20) = 8.28$, $p < .01$, $\eta_p^2 = .29$. Simple main effects showed that while there was no difference in error rate between visual stimuli when hearing bar-related cues ($p = 0.76$), there was a significantly higher error rate for alcohol visual stimuli compared to neutral visual stimuli when there was no auditory cue ($p < .01$). For neutral visual stimuli, there was no difference in error rate between auditory cue type ($p = .77$), but error rates were significantly higher for alcohol visual stimuli when there was no cue compared to when the bar cue was heard ($p < .01$).

[INSERT FIGURE 2 HERE]

Discussion

The current research examined the impact of alcohol-related visual stimuli and auditory cues on inhibitory control. Consistent with predictions, participants were significantly quicker to

respond to alcohol-related visual stimuli on pro-saccade trials. Moreover, they made more errors when responding to alcohol-related relative to neutral visual stimuli on anti-saccade trials. This is in line with previous research suggesting that individuals show greater attentional bias to alcohol-related relative to neutral stimuli (e.g. Albery et al., 2015; Field et al., 2014; Weafer & Fillmore, 2012). Findings also revealed that individual variation in trait effortful control was predictive of inhibitory control performance, with error rates decreasing as effortful control increased. The ability to withhold responses may therefore enhance inhibitory control performance towards alcohol-related stimuli (Qureshi et al., 2017), which in the current study was shown irrespective of self-reported drinking behaviour.

Findings also indicate that participants made fewer errors when alcohol-related auditory cues were presented compared to when no sound cue was presented. However, this facilitatory effect only occurred when bar sounds coincided with the presentation of alcohol-related visual cues, and not neutral visual cues. These findings are consistent with that of Leiva et al. (2015), who found that inhibitory performance was facilitated when participants heard auditory sounds that were relevant to the visual stimuli, whereas task irrelevant auditory cues impaired performance. In the current task, participants recognised that the auditory cue represented sounds played in an alcohol-related environment, and therefore the relevance of these sounds may have enhanced performance when participants responded to alcohol-related visual stimuli. Conversely, bar-related sounds did not appear to facilitate responding for neutral stimuli, perhaps because participants deemed such auditory cues to be irrelevant to the target. Such findings may indicate that the introduction of alcohol-related auditory cues may effectively re-contextualise alcohol-related visual stimuli, causing them to have less attentional pull. Whilst speculative, this effect may result from the process of evaluative conditioning, whereby an attitude towards one stimulus is changed through its pairing with another (Jones, Olson & Fazio 2010). In other words, when bar-related auditory

cues are paired with alcohol-related visual stimuli, the overall effect may be to associate the visual stimuli with a familiar context, lessening their novelty and reducing any impact on inhibitory control.

Whilst further research in this domain remains prudent, these findings may have a number of important implications. First, they may suggest that attentional bias to alcohol-related visual cues in the laboratory may not be observed consistently, or to the same degree, when testing occurs in different environments and/or during exposure to a more diverse array of cues. Previous research which only employs alcohol-related visual targets may therefore exaggerate the effect of alcohol-related attentional biases by studying them in relative isolation from other ecologically valid contextual cues. Second, interventions which seek to draw upon such paradigms as a means of effectively re-training inhibitory control (e.g. Jones & Field, 2013) should be aware of the variable dis-inhibitory effect of different alcohol-related stimuli modalities targeting different senses (c.f. Monk, Sunley, Qureshi, & Heim, 2016). This may have important implications when it comes to the effective implementation of such training in the real world, where individuals are surrounded by a variety of sights and sounds associated with alcohol.

Limitations

As an explorative study, the current study is the first of its kind to examine the effect of introducing alcohol-related auditory cues into the more traditional examination of alcohol-related ocular inhibition. However, there are limitations in the scope and generalisability of the current findings and future research: First, increasing the number of alcoholic and non-alcoholic stimuli included within the anti-saccade task and assessing their respective valence and arousal would be advisable to control for any familiarisation or practice effects. Presently, we accept that the alcohol-related stimulus may have been more visually attractive

than the neutral cue (a green rectangle), meaning that it drew attention regardless of its association with alcohol. If this were the case, however, both slower anti-saccade latencies and higher error rates for the alcohol-related stimuli would be expected. On the contrary, the findings indicate that only error rates were higher for the alcohol-related stimulus, but participants were quicker to launch anti-saccades away from alcohol-related visual stimuli. As such, there are reasonable grounds on which to assert that this performance difference can be attributed to the alcohol-related nature of the stimuli, rather than any inherent differences in the visual attractiveness of the stimuli. Moreover, future research may benefit from employing other appetitive control stimuli. Such comparisons between alcohol-related appetitive and neutral non-appetitive cues are present in the majority of studies in this field (e.g. Kreusch et al., 2013; c.f. Monk et al., 2017 for related discussion). Yet, this means that researchers cannot assuredly separate attentional biases to alcohol-related appetitive cues from other non-alcohol-related appetitive cues (c.f., Adams, Ataya, Attwood, & Munafò 2014).

Based on pilot studies, the current research compared an alcohol-related auditory cue to no sound, in order to simplify the study design, maintain statistical power, and provide an absolute contrast to the alcohol-related stimuli. However, bar-related auditory cues were found to facilitate response latencies to both alcohol-related and neutral visual targets, suggesting that short bursts of sound may therefore arouse participants and trigger a response. Further exploration of the comparable effect of varying auditory cues is therefore recommended.

Research has demonstrated that differences in inhibitory control emerge between intoxicated relative sober individuals (c.f., De Wit, 1996; Roberts, Miller, & Weafer, 2014; Weafer & Fillmore, 2015). Whilst participants were asked to remain abstinent from alcohol prior to participating in the current study, we did not verify this using an objective

breathalyser reading. It must therefore be noted that although the admittance of intoxicated individuals was highly unlikely in this study, any inadvertent inclusion of non-sober participants would have the capacity to impact the validity of the results. Finally, the participant sample was predominantly university students, who are immersed typically in a social, pub-based drinking culture (Straus & Bacon, 1995). As such, context-related cueing might be particularly likely (Rumelhart & Todd, 1993) and future research beyond this sample is recommended.

Conclusion

The current findings are the first to indicate that visual and auditory alcohol-related cues differentially impact inhibitory control performance. Specifically, auditory cues may re-contextualise visual stimuli into a more familiar setting that reduces their saliency and lessens their attentional pull. Moreover, trait effortful control may predict an individual's ability to respond to external stimuli, with greater effortful control facilitating inhibitory performance. These findings suggest that inhibitory control levels may vary in real-world alcohol-related environments where individuals are surrounded by associated sights and sounds, and this may impact their ability to control consumption behaviour. Such findings may have implications for alcohol interventions, which in order to be effective, must be capable of taking into account such contextual and individual variations in inhibitory control.

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Tables

Table 1.

Means (and corresponding standard deviations) for pro- and anti-saccade response latencies as a function of visual stimuli and auditory cue.

	Anti-saccade		
	Alcohol-Related Stimuli	Neutral Stimuli	Visual Stimuli collapsed
Alcohol auditory cue	278.20 (52.29)	282.94 (56.77)	280.57 (53.65)
No cue	318.79 (52.29)	319.95 (58.39)	319.37 (53.00)
Audio cue collapsed	298.50 (55.67)	301.44 (59.98)	--

	Pro-saccade		
	Alcohol-Related Stimuli	Neutral Stimuli	Visual Stimuli collapsed
Alcohol auditory cue	223.65 (45.01)	236.27 (49.20)	229.96 (45.23)
No cue	241.54 (52.76)	262.10 (57.66)	251.82 (52.18)
Audio cue collapsed	232.59 (46.77)	249.18 (50.50)	--

Figures

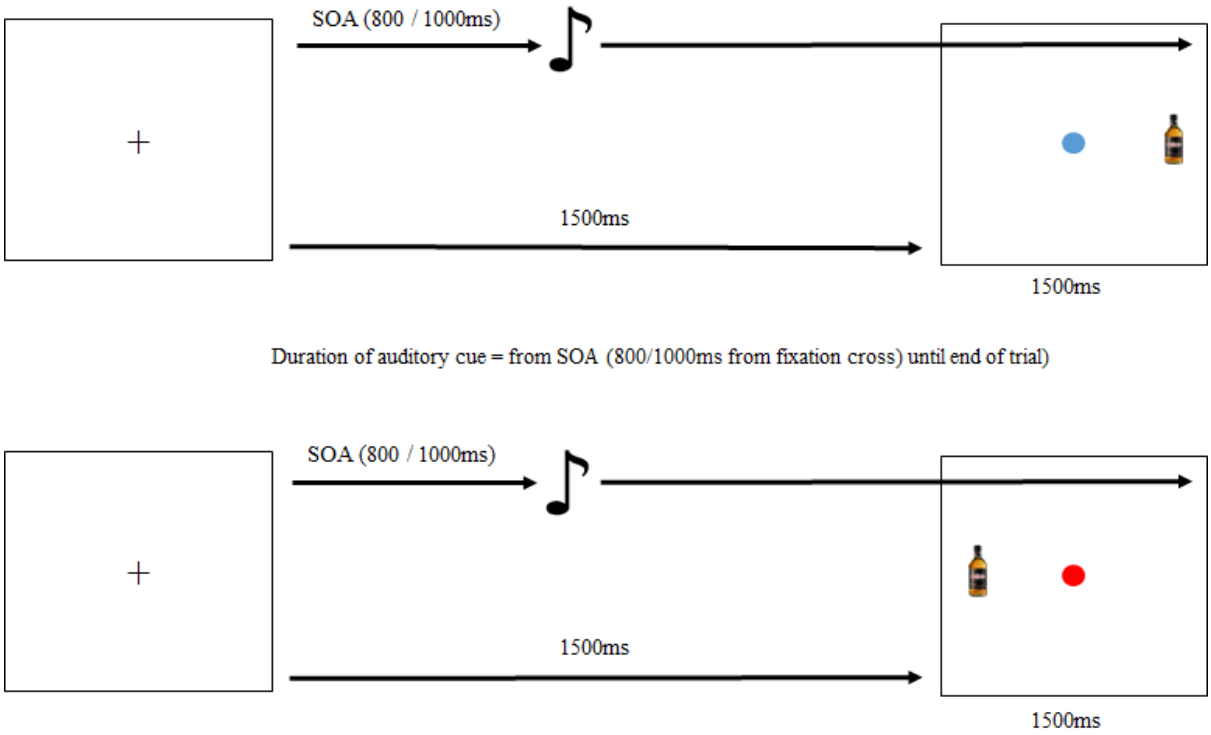

Figure 1.

Example pro-saccade (top) and anti-saccade (bottom) trial procedures.

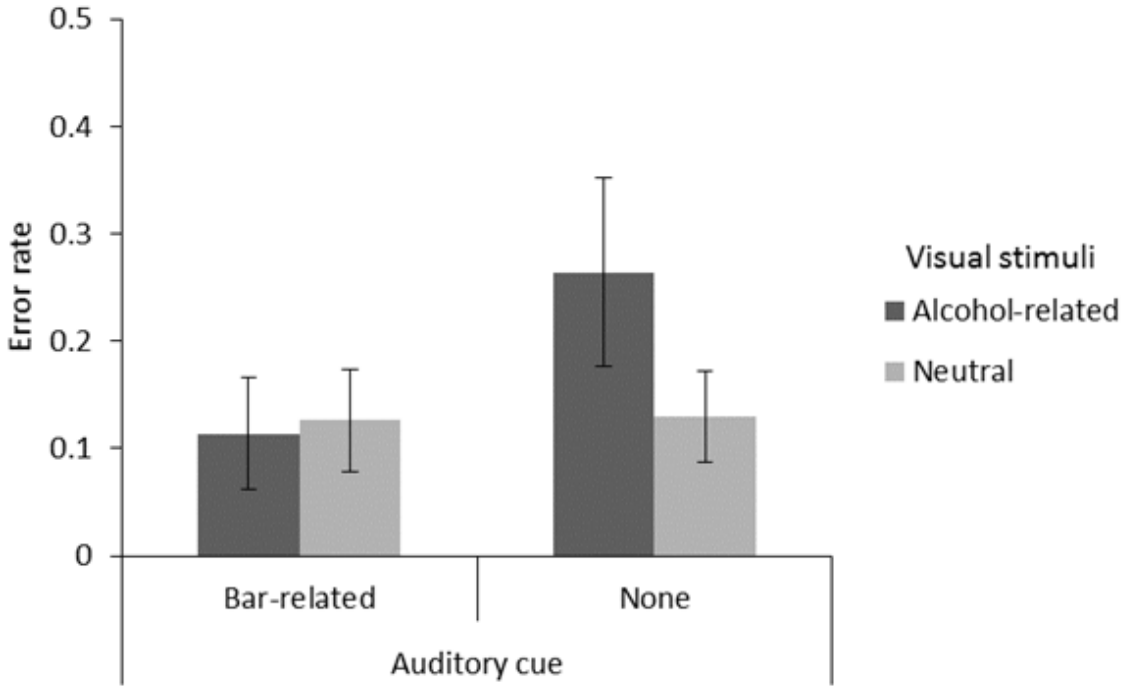

Figure 2.

Mean error rates (and confidence intervals) by visual stimuli (alcohol-related*neutral) and auditory cue (bar-related*none).

Supporting Information File 1

Validation of sound cues utilised in the final study.

Pilot Study 1:

In a first pilot study (*n* = 10), participants were asked to listen to a series of auditory clips containing social alcohol-related (e.g., sounds of a pub) and neutral social sounds (e.g., sounds of an office/work environment). They were then asked to rate these in terms of how representative they were of the intended environment (1 = sound file accurately portrayed the intended sound; 10 = sound file did not accurately portray the intended sound). The highest rated clips for the pub environments were used in the final presented study.

Pilot Study 2:

A second pilot study (*n* = 66) of the anti-saccade task was conducted which introduced an additional audio cue of supermarket noise (a neutral noise). This cue was found to affect latencies differentially from both alcohol-related (bar) and no cues; more errors were made in the anti-saccade task, and there were more errors to alcohol images when the supermarket cue was played. However, less errors were made towards alcohol images when the bar cue was played. This suggested that the observed differences in inhibitory control-related performance were not the product of drawing comparisons between any noise and no noise; rather, it reflected the contextual influence of alcohol-related auditory cues. Accordingly, in the final study presented here, the neutral cue was removed to simplify the study design.