Effects of alcohol and task difficulty on visual tracking and inattentional blindness

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On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Abstract

Rationale

Inattentional blindness (IB) describes the failure to notice salient but unexpected stimuli in one's focal visual field. It typically occurs while performing a demanding task (e.g., tracking and counting basketball passes), which consumes attentional resources. Alcohol intoxication is also known to reduce attentional resources, thereby potentially increasing IB and disrupting task performance.

Objectives

To test the extent to which acute alcohol and task difficulty disrupt counting performance and increase the rate of IB across two experimental tasks.

Methods

To test the effects of alcohol consumption and task difficulty on IB we used the Simons and Chabris (1999; 2010) "gorilla in our midst" basketball clip in Experiment 1, and abstract but analogous stimuli presented in a computerised alternative to that task in Experiment 2.

Results

IB was associated with increased (counting) task difficulty but not alcohol consumption. However, counting accuracy was impaired by both alcohol and increased task difficulty, with the largest detriment being for alcohol participants who noticed the salient but unexpected stimulus.

Conclusion

The absence of alcohol effects on IB in both experiments was unexpected and warrants further investigation in a field vs lab study comparison, and in combination with baseline cognitive measures to test for alcohol expectancy and task compensation effects.

Understanding the effects of alcohol intoxication on attention has long been a focus of systematic empirical research investigated in a range of field and laboratory studies. Examples include studies of selective attention (Canto-Pereira et al. 2007), divided attention (Bayless and Harvey 2017; Moskovitz and Sharma 1974; Schulte et al. 2001), focal attention (Harvey 2015), negative priming (Fillmore et al. 2000), inattentional blindness (Clifasefi 2006; Harvey et al. 2018) and driving performance (Ogden and Moscovitch 2004; Voas Tippetts and Fell 2000). The adverse effect of alcohol on attention is commonly explained by Alcohol Myopia Theory (AMT, Josephs and Steele 1990; Steele and Josephs 1990). According to AMT, alcohol restricts the scope of people's attention to only the most immediate internal or external cues, to the detriment of processing peripheral or less salient information. AMT was initially applied to social contexts in which drinkers focus narrowly on goal-relevant cues at the expense of anticipating the longer-term consequences of their actions, which increases the likelihood of risky or unlawful behaviour (e.g., unprotected sex, violence, etc.). AMT has since been used to explain the effect of acute alcohol on a range of cognitive functions, for instance, reduced recall of information of only peripheral importance in a social encounter (Schreiber Compo et al. 2011) or spatially peripheral in visual scenes (Harvey et al. 2013; Jaffe et al. 2019), and salient facial features, such as hairstyle (Harvey and Tomlinson 2019).

There are two complementary mechanisms that might explain how alcohol narrows the scope of attention. One is based on the attentional spotlight metaphor (Posner 1980) and the other on perceptual load theory (Lavie 2006, 2014). Evidence from eye-tracking studies demonstrates that alcohol reduces eye movements to peripheral areas of a visual display (Harvey et al. 2013; Harvey 2014). This may reflect a restriction of the "beam" or "spotlight" of attention (Posner,1980), which may reduce the range of focal information processed. Nevertheless, information pick-up outside this range is still possible as covert attention to peripheral locations may continue to cue active gaze shifts to these regions (Findley 2005) despite a narrowing of overt attention.

Within the framework of perceptual load theory, the narrowing of attention by alcohol may be conceptualised differently to the attentional spotlight metaphor. Lavie (2006, 2014) proposes a limited capacity approach to selective attention in which a mechanism with finite resources processes all information until capacity is reached. Load is determined by the perceptual processing demands of a task which, in experimental contexts, may be varied by manipulating the complexity of the visual display. For example, a target presented with few distractors carries a lower perceptual load than one presented with many distractors. When perceptual load is low the primary task does not exhaust processing capacity, so spare resources are immediately allocated to the processing of lower priority peripheral information. But in situations of high perceptual load the primary task demands more capacity, thus reducing the amount available for peripheral information capture. As alcohol is thought to limit cognitive resources (Curtin and Lang 2007; Harvey and Seedhouse 2021), primary tasks that do not exhaust attentional capacity when performed sober may do so when performed in an intoxicated state. Caparos and Linell (2010) have demonstrated that an increasing perceptual load restricts the attentional "spotlight", and evidence alcohol may have a similar effect on attentional performance was demonstrated more recently (Bayless and Harvey 2016; Harvey Bayless and Hyams 2018). Bayless and Harvey (2016) manipulated load by increasing the stimulus array size in a visual processing task. Participants were instructed to count the flashes of a centrally presented cross while simultaneously monitoring the colour of dots presented peripherally.

Alcohol impeded peripheral but not central task performance, but only for the low perceptual load version of the task. Presumably, the high load task was so demanding that it left no spare resources for alcohol to deplete (Bayless and Harvey 2016).

The consequences of perceptual load on peripheral attention are similarly demonstrated in studies of inattentional blindness (IB). IB describes an observer's failure to notice stimuli in full view due to the ongoing attentional demands of a primary but unrelated visual task (Mack and Rock 1998; Most 2001). In addition to many lab-based observations, incidences of IB have been reported in naturalistic scenarios. One example is the case of a police officer convicted of perjury for claiming not to have seen an assault en route to another call out (Lehr 2009; see also Chabris et al. 2011). Another is of failures to notice highly unusual and salient stimuli when attention is divided, such as walking while talking on a mobile phone (Hyman et al. 2011). The phenomenon of IB has important real-world relevance, for example, in the context of witness testimony. Cullen et al. (2020) have demonstrated the impact of witness IB on juror perceptions of witness credibility. Theories explaining the mechanisms of IB reflect the fact that increasing the perceptual load of a task increases the IB rate (Cartwright and Lavie 2006). We believe it is of complementary importance to understand the effects of acute alcohol on a viewer's ability to detect and process unexpected stimuli when engaged in a demanding primary task (e.g., driving).

Clifasefi et al. (2006) used what is now the canonical IB paradigm to investigate the impact of alcohol on IB. They presented participants with the Simons and Chabris (1999) "gorillas in our midst" video clip showing two basketball teams (black- vs. white-shirts) each passing a ball to fellow team members. A few seconds into the clip a female dressed in a gorilla costume walks into the middle of the game, faces the camera, thumps her chest then walks on out of view. Participants must count the number of ball passes made between only white shirt players and, after the clip, are asked if they noticed anything unusual about the scene. Clifasefi et al. proposed two competing hypotheses. The first, in accordance with AMT, was that alcohol participants would be less able than sober controls to attend to stimuli outside the central pass counting task, so were therefore less likely to spot the gorilla – thereby showing *higher* rates of IB. The second was that intoxicated participants would struggle to stay on-task while counting the passes and this defocusing of attention would make them more likely to notice the gorilla – thereby showing *lower* rates of IB. Amongst the sober group 46% reported noticing the gorilla, but only 18% of the intoxicated participants did so. The authors' findings were therefore consistent with AMT and their first hypothesis. The attention of intoxicated viewers seemed to be narrowed by alcohol on to the primary counting task, reducing the likelihood of noticing unexpected but salient information.

While these results are striking, Clifasefi et al. (2006) provide no objective evidence of central task engagement. Harvey et al. (2018) later addressed this limitation by extending the design in three important ways. Firstly, pass counting accuracy was recorded as a measure of primary task focus, providing a stronger argument relating to the attentional mechanisms underlying IB. Secondly, primary task demand was manipulated to compare the influence of high and low perceptual load on task accuracy and IB. This was accomplished by asking half the participants to count all passes made by the white shirt team (low load), and half to keep a separate count of that team's aerial and bounce passes (high load). Finally, the video clip included three unexpected events and by recording how many of these participants noticed, a scale measure of IB was used as a DV, which is more sensitive than recording a binary (e.g. gorilla spotted/not-spotted) response. This was a field study carried out in a naturalistic bar setting where casual drinkers were invited to participate. Increasing blood alcohol concentrations (BAC) were associated with a greater likelihood of IB. Furthermore, this was the case for the low perceptual load version of the task but not the high perceptual load version. As in the Bayless and Harvey (2016) study, the authors suggest that with the low load task surplus attentional resources are depleted by alcohol, resulting in a greater likelihood of IB. Whereas, for the high load task there are no spare resources for alcohol to deplete, producing an intoxicated noticing rate comparable to the sober rate. These findings lend support to the perceptual load explanation of attentional restrictions under alcohol, which is consistent with the narrowed attentional spotlight account of AMT.

In the present study we measured attentional performance following alcohol under high/low perceptual load conditions. The Simons and Chabris (1999) gorilla task was shown following tightly controlled alcohol administration in a laboratory setting using a randomised placebo-controlled alcohol administration procedure (Experiment 1). In Experiment 2, for even greater control, we aimed to replicate the effects of alcohol on IB using an abstract, computerised IB task analogous to the original Simons and Chabris (1999) gorilla task. This involved categorising and counting specific movements of dynamic objects – a selection of moving and "bouncing" letter shapes). "Bounce" counting accuracy was recorded and at the end of each trial participants were asked to report anything unexpected. In both experiments half the participants completed a high perceptual load version of the task and half a low load version (subsequently referred to as high and low load conditions). In a fully crossed design, participants were administered either an alcohol or placebo beverage.

We expected the low load task to increase unexpected event noticing relative to the more demanding high load condition. Moderate alcohol intoxication was expected to narrow attention to the counting task thus reducing unexpected event noticing relative to placebo controls. The combination of a high load task and alcohol was expected to produce the lowest spotting rate of all. We predicted that counting accuracy would be poorer for the high than low load task, poorer in the alcohol group than amongst placebo controls, and lowest for alcohol drinkers in the high load condition. Finally, we explored the effect of unexpected event noticing on counting accuracy and predicted one of two possibilities. That noticers would show poorer counting accuracy than non-noticers, due to the interrupting effect of spotting the unexpected event. Or, that noticing would have no effect on counting accuracy because the larger attentional capacity that drives noticing may also facilitate counting performance.

Experiment 1

Method

Participants

The participants all took part in one of two other alcohol research studies in our laboratory. Sample size was therefore determined by a pragmatic strategy to maximise resources (and work around resource limitations, see Lakens, in press), and with the ethical consideration of engaging participants with several tasks following alcohol intoxication. Seventy-nine participants (43 female) who were given either course credit or a small honorarium of £15 for their time. Ages ranged from 18-63 years (*M* = 23.01, *SD* = 7.14). The study protocol adhered to the guidelines of the British Psychological Society, and ethical approval was granted by the host institution's ethics committee. Individuals who expressed interest in participating were included if they were at least 18 years of age and passed the inclusion criteria set out in a suitability screening form. Anyone who did not pass screening or reported a medical contraindication to consuming alcohol was not included in the study.

Design

Participants were randomly assigned to an alcohol treatment group (alcohol vs. placebo), and a task difficulty level (high vs. low perceptual load) in a fully crossed independent-groups design. The frequency of noticing the unexpected gorilla was noted for each participant and submitted to a log-linear analysis. Participants were then categorised as noticers or non-noticers and a 2(alcohol) × 2(task difficulty) × 2(unexpected event noticing) independent ANOVA was carried out on pass-counting accuracy scores.

Materials

Intoxication levels were measured using a Draeger Alcotest 6510 Fuel Cell Breathalyzer. This device is a professional screening tool, which is Type Approved by the UK Home Office and used by UK police forces. The units of measurement were grams of alcohol per 210 litres of breath (g/210 L), recorded in participants' deep lung air. This measurement is equivalent to grams of ethanol per 100 ml of blood (blood alcohol concentration, BAC). The drink driving limit in England and the USA is 0.08% BAC which is approximately BrAC of 0.08 g/210 L of breath. For ease of reading, all BrAC measurements will be expressed as the BAC equivalent. The video shown to participants was the "Monkey business illusion" (Simons 2010) which is a modified version of the original Simons and Chabris (1999) clip. The video shows two teams (white and black shirts) each passing a basketball to players within their own team whilst moving around a small stage. The clip lasts 30 seconds, and the two basketballs stay in play throughout. At 17 seconds a person dressed in a gorilla costume walks onto the centre of the stage from the right, faces the camera, makes a chest thump, then walks off stage to the left. The video clip was played on a 15" laptop positioned at a comfortable viewing distance.

Procedure

The data for this experiment were collected alongside two other studies in our lab, advertised as either a study on attention (Harvey 2016) or a study on attention and face memory (Bayless et al. 2018)[1]. Participants were asked to complete a screening form before attending the lab and were only invited to participate if they fulfilled the following criteria: at least 18 years old, no reported medical contraindications to consuming alcohol, within the weight range (55-95kg), and a regular social drinker who had consumed at least 6 units of alcohol in one drinking session at least once in the past. Any individuals who did not satisfy the initial screening criteria were thanked for their interest but not invited to participate. Participants were asked to eat a light meal at least two hours before attending the study to help match the alcohol absorption rate across participants. On arrival for testing they were provided with a study information form and invited to ask questions. During briefing and

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[1] In both experiments the inattentional blindness task was the last test participants completed. The preceding test was either an attentional flanker task (Harvey 2016) or a face processing task (Bayless et al. 2018)

consent each participant was invited to stay in the laboratory at the end of the study until their BAC was below 0.08%. Those who declined completed a waiver acknowledging that they should not drive or take part in any risky activity should they choose to leave the research venue with a blood alcohol concentration (BAC) at or above 0.08% at the end of the study.

Participants were randomly assigned to one of two alcohol groups (alcohol or placebo) but were naïve to the allocated treatment. The study employed a placebo design to control for alcohol expectancy effects, in line with other recent research (Clifasefi et al. 2006; Harvey 2016; Harvey et al. 2013a b; Schreiber Compo et al. 2011). It has been demonstrated that alcohol expectancy can result in participants adjusting their effort or behaviour to compensate for anticipated lower performance under the influence of alcohol (Fillmore and Blackburn 2002; Testa et al. 2006). Testa et al. (2006) have suggested the use of placebo conditions to address these possible effects. The alcohol administration schedule used in this study is consistent with recent studies using a comparable procedure to achieve the desired BAC levels at the start of the experimental tasks (Clifasefi et al. 2006; Harvey 2016; Harvey et al. 2013a, b; Schreiber Compo et al. 2011). Before commencing the study, a BAC reading was taken to ensure a baseline of 0%, and the participant's weight recorded to the nearest kg. All beverages were prepared out of view. For participants in the alcohol group the drink consisted either of 0.8ml of ethanol (95% ABV) per kg of bodyweight (see Harvey 2015) or 2ml of vodka (37.5% ABV) per kg bodyweight which was topped up to 450ml of drink with tonic water and mixed thoroughly. Participants in the placebo condition received 450ml of tonic water, with 1ml of ethanol dispersed on the surface of the drink. The outside of the glass was misted (two sprays) with ethanol to create the smell of an alcoholic beverage. Participants were asked to consume their drink gradually over the course of 15 minutes, followed by 15 minutes rest before task commencement. Following the 30-minute interval, a second (undisclosed) BAC reading was taken, and participants were asked for their subjective level of intoxication on a scale from 1 (*"I feel completely sober"*) to 10 (*"I feel extremely drunk"*).

Participants were then seated comfortably at a computer where further instructions were provided verbally. The experimental task was described as a test of attention skills with the focus being to count the number of white-team ball passes as accurately as possible. Those randomly assigned to the low load task were told to count the total number of passes made by this team, while those assigned to the hard task had to keep track of both the number of aerial and bounce passes. Following the conclusion of the game participants reported their pass counts and were asked whether they noticed anything unexpected during the clip. Once their responses were recorded, they were asked if they were familiar with the gorilla clip, and whether they had suspected anything suspicious about the task. Two participants admitted having seen the clip previously, so their data were excluded from all further analysis. A full debrief was provided, along with a final breath alcohol measurement, which was disclosed to participants prior to leaving the lab (no-one chose to remain in the lab). Participants who had received alcohol were reminded not to drive or engage in any other activity that is compromised by alcohol (e.g., cycling in traffic).

Results and Discussion

Alcohol Treatment

Thirty minutes after beverage consumption the mean BAC for the alcohol group was M = 0.07% (SD = 0.02) and, for the placebo group, M = 0.00% (SD = 0.00). The subjective intoxication rating of the placebo group was lower (*M* = 1.97, *SD* = 1.59) than that of the alcohol group (*M* = 5.43, *SD* = 1.55), but significantly greater than one, t(38) = 3.97, p < .01, indicating that the placebo control generated some alcohol expectancy.

Inattentional Blindness

The overall unexpected stimulus noticing rate was 47%. Rates of noticing across the alcohol and task difficulty conditions, shown in Table 1, were submitted to a 2(alcohol) x 2(task difficulty) x 2(unexpected stimulus noticing) log-linear analysis. There were no significant effects or interactions (all *p* > .287). Unexpected stimulus noticing was unaffected by changes in alcohol state or task difficulty.

[TABLE 1 ABOUT HERE]

Alcohol consumption did not increase IB (there was no difference to these findings when the effects of alcohol were considered for the easy and hard tasks separately). This is surprising as it is inconsistent with the results of Clifasefi et al. (2006) and Harvey et al. (2018). The unexpected stimulus noticing rate across all participants is much lower in Clifasefi et al. (33%) compared to Harvey et al. (43%) and the current study (47%). However, this seems to be carried by the very low rates of noticing in Clifasefi's intoxicated group. Amongst sober participants, noticing rates are similar (46% in Clifasefi et al.; 42% in the present study; the Harvey et al. design precluded a sober control group).

The significant alcohol effect in Clifasefi et al. was achieved at a low level of intoxication (BAC = 0.04%), so it is surprising that noticing rates were not affected in the current study in which the mean intoxication level was higher (BAC = 0.07%). It is not possible to compare directly to Harvey et al. as participants were not categorised by alcohol group in their field study. This lack of alcohol effect on IB is followed up in Experiment 2 using an abstracted IB paradigm.

Task Accuracy

Counting accuracy was calculated by taking the absolute (ABS) value for the difference between the actual bounce number and the reported bounce number, dividing this by the actual bounce number and expressing it as a percent correct measure (percent correct = 100 – (ABS(actual – reported)/actual)*100.)

[FIGURE 1 ABOUT HERE]

Accuracy scores, summarised in Figure 1, were submitted to a 2(alcohol treatment) × 2(task difficulty) × 2(noticed gorilla) between-subjects ANOVA with a one-tailed hypothesis for alcohol treatment and task difficulty (predicting lower accuracy scores in the alcohol and high load groups, respectively). The results of this analysis are summarised in Table 2. As expected, accuracy scores were higher for the low load (M = 97.29, SE = 1.66) than for the high load (M = 76.99, SE = 1.71) counting task, p < .01, 95% CI [15.50, 25.04]. There was no effect of alcohol on counting accuracy (M_{diff} = -0.41, SE = 2.38, p = .87, 95% CI [-5.15, 4.34]).

The significant interaction between task difficulty and unexpected stimulus noticing was followed up with pairwise comparisons (with a Bonferroni correction). With the high load task, those who noticed the gorilla had significantly poorer counting accuracy than those who did not (M_{diff} = -13.79, *SE* = 3.42, *p* < .01, 95% CI [-20.60, -6.98]. There was no such difference for the low load version of the task (M_{diff} = 1.21, *SE* = 3.31, *p* = .72, 95% CI [-5.40, 7.81].

As predicted, counting accuracy was lower in the high load version of the task, which is consistent with Harvey et al's (2018) findings. A comparison with the findings of Clifasefi et al. (2006) is not possible as they did not report primary task accuracy data. Surprisingly, however, counting accuracy in the present study was unaffected by alcohol under both low and high task load conditions. This was unexpected since Harvey et al. found a negative association between increasing BAC and accuracy scores (in addition to an association between task difficulty and accuracy). Nevertheless, alcohol intoxication did impair counting accuracy in our low load task. It did not impair hard task performance but we presume this is because the higher load in that condition left no spare capacity for alcohol to deplete (cf. Harvey et al. 2018).

One concern with our use of the basketball clip is that prior participant knowledge of it may have been more of an issue among our sample of undergraduate students (some of whom were studying psychology) relative to Clifasefi et al's (2006) sample comprising members of the general public. This problem is further compounded by the wide publicization of Simon and Chabris' gorilla clip, free to view on YouTube since 2010. Participant naivety is a major concern because Simons (2010), perhaps unsurprisingly, observed a gorilla spotting rate of 100% among viewers with prior knowledge of the gorilla scenario. While we excluded data from only two participants due to prior knowledge of the clip, others may have failed to disclose their knowledge of it due to a social desirability bias or through having only implicit awareness of the scene. To follow up on our Experiment 1 findings we therefore designed an abstracted version of this IB paradigm to use in Experiment 2, as it was far less likely to be recognised as an IB test. A further advantage of this alternative IB task is that the perceptual features of the task relevant and (unexpected) irrelevant stimuli can be adjusted to maximise the likelihood of IB (Most et al. 2000, 2001, 2005). By calibrating the featural overlap between these stimuli, we reduced the likelihood of perceptual "pop-out" effects for the unexpected stimuli. For example, by using alpha-numeric letters and characters with similar features, such as "L", "T" and "+", as opposed to "A". In sum, the abstracted IB task therefore addressed two limitations of Experiment 1: the familiarity problem and the fixed contrast between expected/unexpected stimuli.

Experiment 2

The purpose of this experiment was to overcome the problem of participant familiarity with the Simons and Chabris (1999) gorilla scene through use of an analogous computer-based IB test using dynamic abstract symbols. In this task, originally conceptualised by Most and colleagues (2000, 2001, 2005), two sets of shapes move inside a square frame in straight trajectories then, on touching the frame, "bounce" off it and continue moving in the rebounded direction. These stimulus sets differ on one dimension such as shape or colour. The task is to count the bounces of one shape subset and report this count after each trial. On critical trials an unexpected stimulus moves across the display. Most et al. (2005) consistently manipulated the characteristics of the unexpected stimulus to examine the circumstances under which observers were most likely to notice it. They demonstrate that unexpected stimulus noticing is strongly determined by attentional set, such that even distinct stimuli that fall outside of the set may be missed. Our task is an adaptation of Beanland and Pammer's (2010) version in which observers count and record the bounces of two white letters ("T" and "L") while disregarding the same letters shown in black font. On two critical trials a greyscale symbol crosses the screen on the horizontal midline. Finally, after completing five trials, participants are asked whether they noticed anything unexpected during the task.

In addition to reducing task familiarity to an absolute minimum, this alternative task has the benefit of including two critical IB trials in which an unexpected stimulus is presented. Bressan and Pizzighello (2008) show that the first critical trial does not implicitly alert viewers to a second unexpected stimulus provided it is different to the first and that participants are not questioned about them until the end of all trials. To replicate the perceptual load manipulation of Harvey et al. (2018), participants completed one of two versions of the task. A "low load" version, requiring a bounce-count of only one type of white letter (e.g. "Ls"), or a "high load" version requiring bounce counts for two types of white letters (e.g. "Ls" and "Ts").

The predictions for this experiment were the same as for Experiment 1. We expected the increased perceptual load of the hard task to decrease unexpected stimulus noticing. Should alcohol have any effect, we thought it would be in reducing the rate of unexpected stimulus noticing, bounce counting accuracy or both, relative to placebo controls. Counting accuracy was expected to be lowest for alcohol participants of the high load task. Finally, we expected unexpected stimulus noticers to show poorer counting accuracy than non-noticers, particularly under high load conditions.

Method

Participants

The participants in Experiment 2 were part of another alcohol research study carried out in our laboratory. As per Experiment 1, sample size was determined by a pragmatic strategy to maximise resources (and work around resource limitations, see Lakens, in press), and with the ethical consideration of engaging participants with several tasks following alcohol intoxication. Eighty-one participants (63 female) volunteered for either course credit or a small honorarium of £15 for their time. Age ranged from 18 – 40 years, $M = 20.51$, $SD = 3.68$. The study protocol adhered to the guidelines of the British Psychological Society, ethical approval was granted by the host institution's ethics committee, and the inclusion criteria were the same as those of Experiment 1.

Design

As in Experiment 1, participants were randomly allocated to one of two alcohol treatment conditions (alcohol vs. placebo), in a fully crossed design, and to one of two task difficulty levels (high vs low perceptual load). Participants were categorised according to whether they noticed the unexpected stimulus, and this was used as a quasi-independent variable. In addition to these between-subjects groups, a within-subjects variable describing the trial type was included (control trial vs. unexpected stimulus trial). Accuracy scores served as the dependent variable.

Apparatus and Stimuli

Visual stimuli were presented on a 19” computer monitor (60Hz refresh rate, 1280x1024pxl resolution). The experiment was programmed using PsychoPy (Peirce 2009). It consisted of a total of six trials, on each a light grey background was presented with four white and four black letters (for each colour, two “L”s and two “T”s), which moved from randomised starting positions in straight paths around the screen and “bounced” when they reached the edges of the screen (much like a snooker ball bouncing off the table side cushion). Each letter bounced between 3 and 5 times per trial, and the total bounce count varied between 17 and 21. On control trials 1, 2 and 4 there were no additional stimuli, while critical IB trials 3 and 5 each contained one unexpected stimulus, which was dark grey in colour and travelled from right to left across the horizontal midline of the screen. The unexpected stimulus appeared on the right edge of the display at 15° of visual angle, 5 seconds into the trial and disappeared at the left edge at 10 seconds. The two unexpected stimuli were the symbols “+” and “=” (and subtended 2° visual angle) respectively, chosen due to their featural similarity to the “L” and “T” targets. After the fifth trial participants were asked to report whether they noticed anything unexpected. Following their response, the sixth trial began in which a third unexpected stimulus (a greyscale “A”) was presented. On this final full-attention control trial, participants were simply asked to indicate when they saw this additional character, bounce-counts were not required. A schematic diagram of the experiment is shown in Figure 2.

Procedure

Other than a small difference to the alcohol dosage, the recruitment, screening and alcohol administration procedure was identical to that of Experiment 1. Participants in the alcohol group received 0.8ml of ethanol (95% ABV) per kg of bodyweight (adjusted to 0.67ml for female participants; Mumenthaler et al., 1999) mixed with 450ml of sugar free Indian tonic water. Alcohol and placebo beverage preparation and consumption followed the same procedure as Experiment 1. Following the alcohol absorption period, participants indicated their subjective intoxication level on a scale from 1 (“I feel completely sober”) to 10 (“I feel extremely drunk”). They were then seated 60cm from the stimulus display monitor. Participants were randomly assigned to either the high or low load counting condition. In the high load condition participants monitored both sets of white letters (Ts and Ls) and kept separate counts of how often a letter from each set bounced off the display frame. In the low load counting condition participants monitored only the white “Ls” and counted their bounces off the display frame. Participants entered the final count using the keyboard in a pop-up window at the end of each trial. The experiment consisted of six 15 second trials. Trials 1, 2 and 4 were control trials where no unexpected stimulus was presented. Trials 3 and 5 were the critical trials during which the unexpected stimulus was presented (“+” and “=” respectively). After the fifth trial the experimenter asked participants whether they had noticed anything unexpected during the task and their response was noted. If participants reported seeing an unexpected stimulus (an extra shape or letter) they were asked to provide details about it. If they did not report seeing an unexpected stimulus, the experimenter explained that some trials contained an extra stimulus, presented an array of 8 symbols and letters (containing the two unexpected stimuli and 6 foils) and asked participants to indicate whether they thought they saw any of the listed shapes. The response was recorded. During the sixth full attention control trial participants were instructed not to count the letter bounces but to instead observe all on-screen stimuli and report the additional stimulus. The purpose of this final trial was to ensure that participants were able to report seeing the additional stimulus under conditions of full attention. Any data contributed by participants who failed to report the additional stimulus would have been excluded from our analysis. However, all participants accurately reported the additional stimulus in the control trial.

At the end of the experiment a third BAC recording was taken, and participants with a reading at or above 0.08% were encouraged to wait in the laboratory for their BAC to drop below this legal limit for driving. Participants who had earlier signed the release waiver to leave were reminded not to drive or engage in any other risky activity for the rest of the day. All participants chose to leave the laboratory immediately after debriefing, during which they were thanked for participating, given a brief overview of the study aims and hypotheses and reminded not to disclose the details of the experiment to others, particularly those concerning the placebo control.

Results and Discussion

Alcohol Treatment

Mean BAC for the alcohol group was M = 0.06, SD = 0.02 thirty minutes after beverage consumption, and M=0.06, SD = 0.01 at the end of the experiment (approximately 60 minutes after beverage consumption). As expected, the average BAC level for the placebo group was M = 0.00, SD = 0.00. Subjective intoxication of the placebo group was lower (*M* = 2.78, *SD* = 1.19) than for the alcohol group (*M* = 4.78, *SD* = 1.42), but significantly greater than one, t(39) = 9.56, $p < 0.01$, indicating a successful placebo manipulation

Inattentional Blindness

The overall rate of unexpected stimulus noticing was 35%. We submitted the noticing data, shown in Table 3, to a three-way (alcohol treatment x task difficulty x unexpected stimulus noticing) loglinear analysis, which had a likelihood ratio of $\chi^2(0) = 0$, p =1. The highest order interaction was non-significant χ^2 (1) = 0.81, p = 0.37. Partial associations indicated a significant association between task load and unexpected stimulus noticing, $\chi^2(1) = 5.60$, p = 0.02; and an effect of noticing, $\chi^2(1) = 7.31$, p =0.01. Rates of noticing were lower in the high load compared to the low load task, $\chi^2(1, N = 80) = 5.50$, $p < .05$, however, alcohol did not affect the likelihood of unexpected stimulus noticing , $\chi^2(1, N = 80) = 0.22$, p = .64. As expected, perceptual load affected unexpected stimulus noticing, with a higher load increasing IB. The critical alcohol treatment did not increase the likelihood of IB in either the low or high load task condition. Although this is contrary to our predictions and previous research (Clifasefi et al. 2006; Harvey et al. 2018) it is at least consistent with Experiment 1.

[TABLE 3 ABOUT HERE]

Task Accuracy

Accuracy scores were averaged for the two control trials 2 and 4, and the two unexpected stimulus trials 3 and 5. The first trial was considered a learning trial so was excluded from analysis. As in Experiment 1, unexpected stimulus noticing was included in that analysis as a quasi-independent variable. To determine the effects of alcohol treatment, task difficulty and unexpected stimulus noticing on counting accuracy, a 2(alcohol) × 2(task difficulty) × 2(unexpected stimulus noticing) × 2(trial type) mixed analysis of variance was run. While control trials contained no unexpected stimulus for "noticers" to report, the trial-type variable was nevertheless included to check for differences in accuracy amongst noticers regardless of unexpected stimulus presence. The results of the analysis are shown in Table 4.

[TABLE 4 ABOUT HERE]

We hypothesised that both perceptual load and alcohol intoxication would affect accuracy on the primary task. Both these hypotheses were confirmed. There was a significant difference between the two alcohol treatment groups ($M_{diff} = 3.92$, SE = 2.2, $p = 0.04$, 95% CI [-0.47, 8.32]) with lower accuracy in the alcohol group as expected. Accuracy scores in the high load task condition were significantly lower than in the low load task condition ($M_{diff} = -9.27$, SE = 2.20, $p < .001$, 95%CI [-13.66, -4.87]). As there were significant interactions involving both these effects, they will be discussed further below.

The comparison between unexpected stimulus and control trials ($M_{diff} = 0.10$, SE = 1.16, $p = 0.93$, 95%CI [-2.20, 2.40]) was not significant, however, those participants who noticed the unexpected stimulus had significantly lower accuracy scores overall than those who did not, ($M_{diff} = -5.21$, SE = 2.20, $p = 0.021$, 95%CI [-0.81, -9.60]). This main effect was also moderated by significant interaction effects, which are discussed below.

The main effect of alcohol was moderated by two significant interactions, which we followed up with pairwise Bonferroni corrected comparisons. The interaction between trial type and alcohol treatment indicated that in control trials, the alcohol group had lower accuracy scores than the placebo group ($M_{diff} = -6.54$, SE = 2.61, $p = 0.014$, 95%CI [-11.73, -1.34]). This difference was non-significant for trials containing the unexpected stimulus ($M_{diff} = -1.31$, SE = 2.37, $p = 0.58$, 95%CI [-6.02, 3.41]). The deleterious effect of alcohol on task accuracy was thus more pronounced in the control trials than those in which a unexpected stimulus was presented, possibly due to a wider range of performance on unexpected stimulus trials.

Of greater interest was the interaction between unexpected stimulus noticing and alcohol treatment, illustrated in Figure 3. This reveals that noticing impaired accuracy only amongst the alcohol group (intoxicated noticers vs. non-noticers: $M_{diff} = -9.5$, SE = 3.1, $p = 0.002$, 95% CI [-16.03, -3.86]), with no such interaction observed for the placebo group ($M_{diff} = -0.47$, SE = 3.18, 95%CI [-6.81, 5.87]). Beanland and Pammer (2010) did not find an association between counting accuracy and IB and, consistent with that non-pharmacological study, it was not apparent amongst our own sober controls. This suggests a possible trade-off between counting accuracy and unexpected stimulus noticing following alcohol consumption, a possibility explored below.

General Discussion

According to *alcohol myopia theory*, alcohol consumption impairs peripheral attention by depleting cognitive resources. We attempted to replicate findings of two previous studies supporting this view in showing that acute alcohol intoxication increases inattentional blindness (Clifasefi et al. 2006) except when the primary task is do demanding there is no cognitive reserve left for alcohol to deplete (Harvey et al. 2018). In Experiment 1 we used the classic Simons and Chabris (1999) basketball scene to test for IB followed by an analogous abstract version of this task in Experiment 2, to maximise participant naivety. Our predictions and findings for these studies are summed up as follows.

Regardless of alcohol state, we expected lower rates of IB (i.e., more unexpected stimulus spotting) under low rather than high primary task demands, but this hypothesis was only partially supported. In Experiment 1 the spotting rate was stable across task load conditions, but in Experiment 2 there was more evidence of IB (i.e., a lower unexpected stimulus spotting rate) in the high load task, in which participants had to track the motions of stimuli from two visual categories (as opposed to one in the low load task). More importantly, as alcohol is presumed to reduce cognitive capacity, we expected its consumption to increase IB (i.e., reduce unexpected stimulus noticing) relative to the performance of placebo controls, yet we observed no such effect. Alcohol reduced primary task (counting) accuracy as expected, but only in Experiment 2 and only among unexpected stimulus noticers. Also as predicted, unexpected stimulus noticers showed poorer counting accuracy than non-noticers, regardless of alcohol state.

It is unclear why alcohol did not increase the IB rate in our experiments, contrary to prior work (Clifasefi et al. 2006; Harvey et al. 2018). Our alcohol group reached BACs of around 0.06 to 0.07%, higher than those achieved by Clifasefi et al. (2006) (mean BAC = 0.04%) and Harvey et al. (2018) (mean BAC = 0.05%). However, in some cognitive alcohol studies low and high BACs have a greater impact on performance than intermediate levels of intoxication (e.g., Magrys & Olmstead, 2014). This U-shaped function is explained by trivial effects of alcohol at lower doses and participant task compensation effects of alcohol at higher doses, when the perceptual effects of intoxication become apparent to them. It is therefore possible that differences in unexpected stimulus noticing between the present alcohol groups and those of Clifasefi et al. are due to a contrast in compensation efforts between low and moderate intoxication levels. Another possibility is that different alcohol administration protocols drove the discrepant findings. For example, Suchotzki et al. (2020) discuss the problem of alcohol expectancy and the reinforcing effects of social context on alcohol consumption, which they suggest may explain discrepancies between their own lab and field studies (see the meta-analysis by McKay and Share 1999, for a similar argument). Although Clifasefi et al. ran their experiment in a lab, they used a different alcohol protocol to ours. Furthermore, as their participants were members of the public rather than undergraduate psychology students, they were more likely than our participants to be naïve to inattentional blindness paradigms (in particular the basketball clip), and less likely to second guess or try to defeat the aims of the study manipulation (Corneille & Lush, 2021).

It is also important to acknowledge that there is no consistent evidence that cognitive capacity predicts susceptibility to IB. Studies investigating individual differences in working memory capacity and the likelihood of unexpected stimulus noticing report mixed findings and typically only weak associations between cognitive ability and the likelihood of IB (see Kreitz et al. 2015, for a discussion). Kreitz et al. (2015) therefore propose that IB rates are driven by situational or contextual factors, rather than any systematic individual differences. Contextual factors, such as task relevance and participant motivation, may therefore be more predictive of unexpected stimulus spotting than variations in alcohol intoxication.

Despite the absence of an alcohol effect on IB, our unexpected stimulus noticers showed poorer counting accuracy than non-noticers, but not consistently across experiments. In Experiment 1 noticing was associated with poorer counting performance under the high load condition, and in Experiment 2 that relationship was only found among the alcohol group. Nevertheless, our findings are broadly compatible with perceptual load theory and AMT. The unexpected stimulus is designed to be irrelevant to the primary task and is thus best ignored – an inhibition requiring cognitive resources associated with working memory capacity (Lavie et al. 2004; Lavie and de Fockert 2005, 2006). Under the influence of alcohol or while performing a demanding perceptual task, there may be insufficient cognitive reserves to spot a unexpected stimulus while maintaining accurate primary task performance. On the other hand, for sober viewers, or during low perceptual load tasks, spare resources support unexpected stimulus noticing without compromising task accuracy.

Study Limitations

We think the most likely reason for finding no effect of alcohol on IB is differing alcohol administration protocols and test contexts between the present experiments and those of Clifasefi et al. (2006) and Harvey et al. (2018). Clifasefi et al. (2006) manipulated a lower mean BAC level than we did here, while the upper bound of the BAC in Harvey et al.'s (2018) field study extended far beyond ours. Unfortunately, these differences prevent direct comparisons between these experiments. One important consideration is a lack of ecological validity in lab-based alcohol studies. Although this approach affords better control of potentially confounding variables and protocols designed to mimic naturalistic drinking settings, the lab environment tends to moderate the impact of alcohol intoxication on task performance (McKay & Share, 1999). In a recent example of this context effect, Suchotzki et al. (2020) report a null effect of alcohol on cognition in a well-powered lab-based replication of an analogous field study in which a significant effect of alcohol was observed. Given these issues of experimental setting, two methodological improvements should be incorporated into future studies of this nature. The first, a dose-response design to help shed light on the mixed effects seen in alcohol-IB studies conducted thus far. And, the second, greater use of real-world drinking scenarios to improve the ecological validity of this research.

A further potential limitation of the present study is the small sample size. Measured effect sizes in both experiments were small to medium, ranging from $\eta p^2 = .01$ to $\eta p^2 = .07$ (Perugini et al. 2018). As the sample sizes were restricted by resource limitations, a sensitivity analysis (Faul et al. 2007) was carried out to determine the strength of effect that could be reliably detected using our sample size, α-level and expected power. This post-hoc measure of expected effect size was calculated using G*Power version 3.1.9.6 (Faul et al., 2007, 2009), with an alpha error probability of 0.05, power of 0.8, and n=80 participants, which returned a small effect size of Cohen's f=0.14, (Perugini et al. 2018). Effect sizes below this value would not therefore have produced statistically significant results. Our smallest observed effect size equates to Cohen's f = 0.33 (where $f=\sqrt{(\eta p^2/1-\eta p^2)}$, which is well above the minimum determined by the sensitivity analysis Nonetheless, the apparently modest effect of alcohol on visual attentional processes involved in the current tasks may indicate that acute alcohol intoxication has a limited detrimental effect on the visual attention processes investigated in the current tasks. Considering the resource intensive nature of studies of acute alcohol intoxication, careful planning is needed for future investigations of this nature.

Conclusion

The results of this study suggest acute alcohol intoxication does not inevitably increase the likelihood of inattentional blindness, at least at moderate BAC levels and when alcohol participants are able and motivated to make compensatory task efforts. The inconsistent findings among the current studies of alcohol and IB (three in all, incorporating four experiments) therefore underscore the need for more detailed examination of this relationship under a wider range of situational and contextual conditions for any firm conclusions to be drawn.

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Table 1. Cross-tabulation of noticing the unexpected gorilla in each combination of the alcohol and task difficulty conditions.

		Yes	No	Total
Alcohol	High load	10 (43%)	13 (57%)	23
	Low load	10 (59%)	7 (41%)	17
Placebo	High load	6 (37%)	10 (63%)	16
	Low load	11 (48%)	12 (52%)	23

Table 2. Results of 2×2×2 ANOVA (+p-value adjusted for one-tailed hypothesis)

Between subjects' effects	F(1, 71)	*p*	η_p^2
Alcohol	0.03	.44+	0.01
Task Difficulty	72.75	.01+*	0.51
Unexpected Stimulus Noticing	6.99	.01*	0.09
Alcohol × Difficulty	0.46	.50	0.01
Alcohol × unexpected stimulus Noticing	0.45	.51	0.01
Difficulty × unexpected stimulus Noticing	9.94	.01*	0.12
Alcohol × Difficulty × unexpected stimulus Noticing	3.43	.07	0.05

*p<0.05

Table 3. Counts for noticing the unexpected stimulus in each combination of the alcohol and task difficulty conditions.

		Yes	No	Total
Alcohol	Hard	5 (25%)	15 (75%)	20
	Easy	8 (40%)	12 (60%)	20
Placebo	High load	4 (20%)	16 (80%)	20
	Low load	11 (51%)	9 (49%)	20

Table 4. Results of the 2×2×2×2 ANOVA (+p-value adjusted for one-tailed hypothesis)

Within Subjects Effects	F(1, 72)	*p*	η_p^2
Trial Type	0.01	.93	0.01
Trial Type × Alcohol	5.13	.03*	0.07
Trial Type × Noticing	1.15	.29	0.02
Trial Type × Task Difficulty	0.20	.66	0.01
Trial Type × Alcohol × Noticing	0.78	.38	0.01
Trial Type × Alcohol × Task Difficulty	1.92	.17	0.03
Trial Type × Noticing × Task Difficulty	0.34	.56	0.01
Trial Type × Noticing × Task Difficulty × Alcohol	0.05	.82	0.01
Between-subjects' effects			
Task Difficulty	17.67	.00*+	0.20
Alcohol	3.17	.04*+	0.04
Noticing	5.58	.02*	0.07
Alcohol × Noticing	4.62	.04*	0.06
Alcohol × Task Difficulty	0.31	.58	0.01
Noticing × Task Difficulty	0.30	.59	0.01
Alcohol × Task Difficulty × Noticing	0.24	.63	0.01

*p<0.05

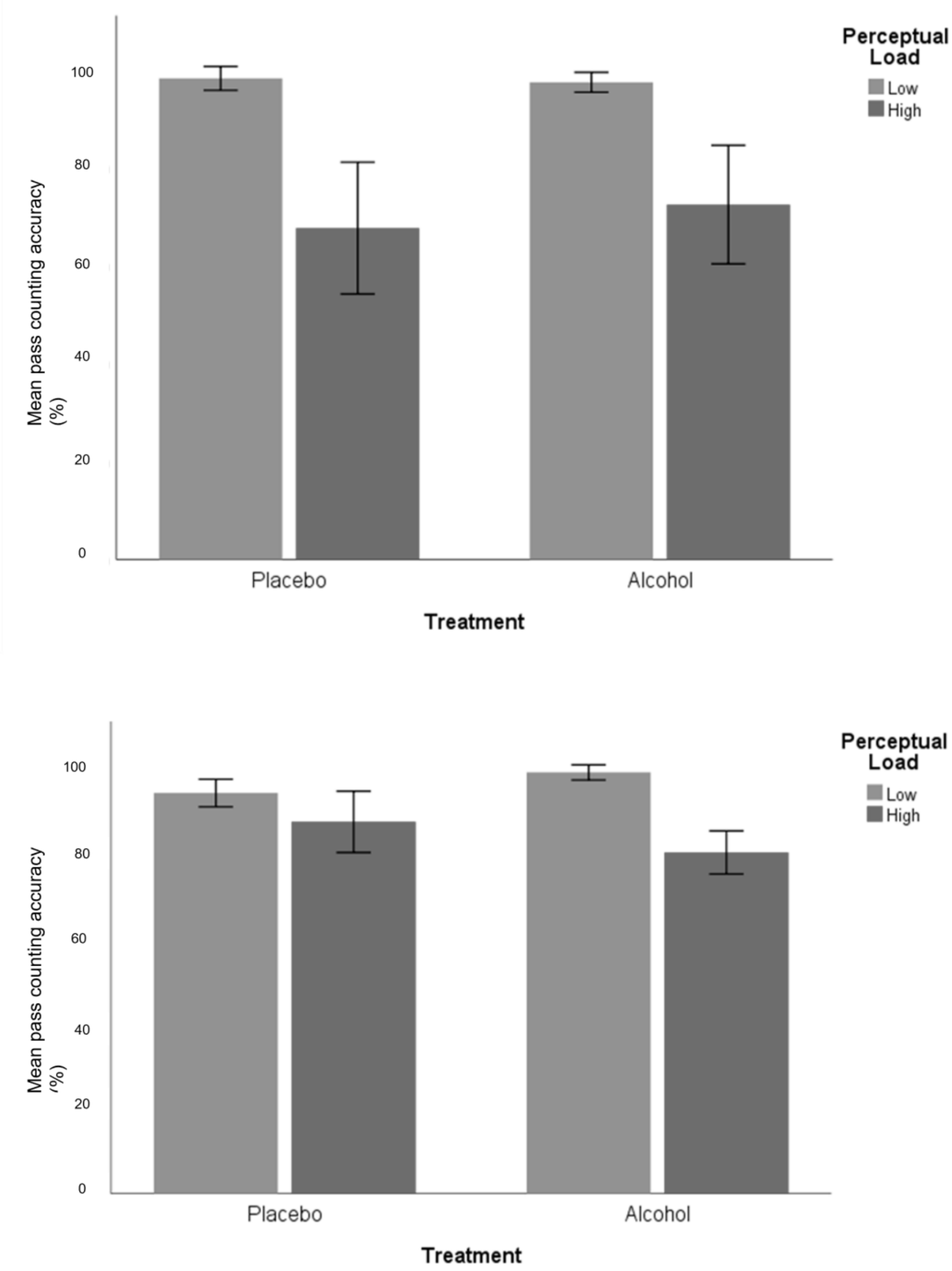

Figure 1. Mean accuracy scores for each alcohol treatment condition and perceptual load group, panelled by gorilla noticing (top panel: noticers, N=37, lower panel: non-noticers N = 42). Error bars show 95% confidence intervals.

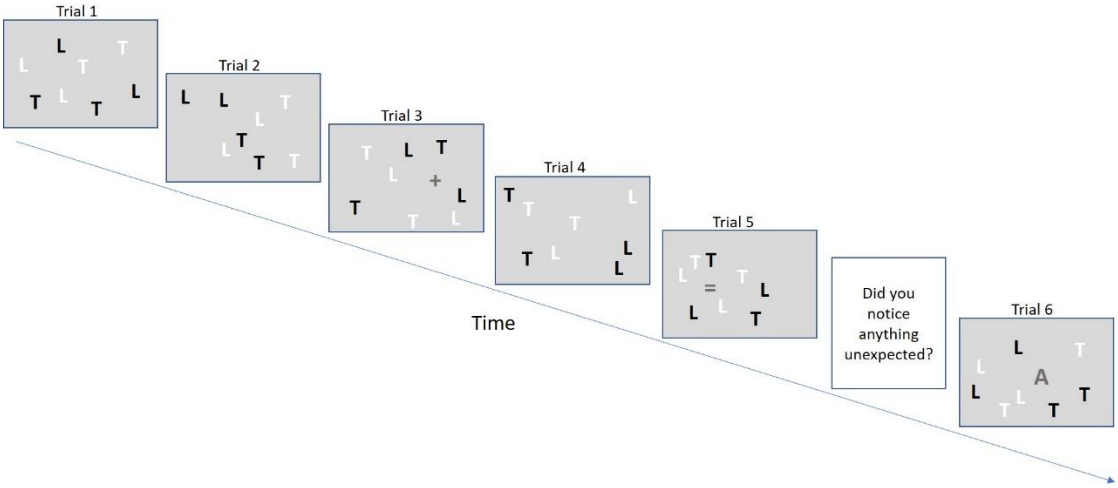

Figure 2. Schematic of trial sequence. Trial 1 is a practice trial and trials 2 and 5 are control trials. On trials 3 and 4 an unexpected stimulus crosses the display across the horizontal midline. Trial 6 is a full attention control trial.

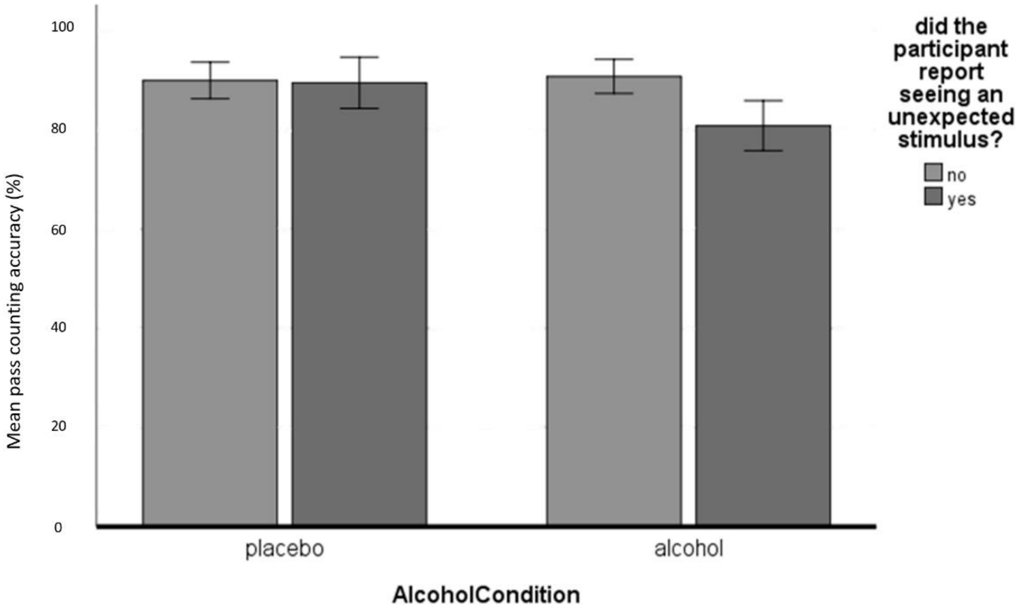

Figure 3. Accuracy scores for placebo and alcohol treatment groups, clustered according to whether the participants noticed at least one of the unexpected stimuli. Error bars show 95% confidence intervals.