When alcohol narrows the field of focal attention

Alistair J. Harvey

University of North Georgia

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Correspondence concerning this article should be addressed to Alistair Harvey, Department of Psychological Science, University of North Georgia, 82 College Circle, Dahlonega, GA 30597

Telephone: (+1) 706-867-2771

E-mail: alistair.harvey@ung.edu

Abstract

The aim of this study was to measure the extent to which alcohol intoxication restricts the scope of attention in the visual field. A group of intoxicated (n = 31; mean BAC ≈ .08%) and placebo control (n = 31; mean BAC ≈ .00%) participants were required to correctly identify visual probes while performing two verbal categorization tasks: one designed to widen the scope of visual attention on to each stimulus word; the other, to narrow attention on to the central letter of each word. Response times to surprise probes interpolated between categorization trials were measured and these catch-trials could appear in any of the stimulus word letter positions. As predicted by alcohol myopia theory (AMT), which assumes the drug narrows focal attention, intoxicated participants made slower responses than sober controls to probes displayed in non-central letter positions, although right-field probe reaction times were slower than those for left-field targets. This response asymmetry and wider theoretical implications of the findings are discussed.

Keywords: Alcohol intoxication, visual attention, reaction time

The predominant theoretical account of the effect of alcohol intoxication on attention is currently *alcohol myopia theory* (AMT), which assumes the drug causes a reduction in attentional capacity with diminished resources prioritized for the processing of only the most immediately relevant stimuli (Josephs & Steele, 1990; Steele & Josephs, 1990). This attention allocation model was developed to explain the social effects of intoxication (e.g., unprotected sex, physical assault) assumed to result from too narrow a focus on central stimuli (e.g., attraction, provocation, etc.) and the neglect of distal cues (e.g., fear of unwanted pregnancy, arrest, injury, etc.), which may otherwise inhibit high risk responses.

Despite its original focus on adverse social behaviour, the attention narrowing mechanism AMT posits is also supported by cognitive studies in which alcohol is shown to slow visual search times for spatially peripheral targets (e.g., Hoyer, Semenec & Buchler, 2007; Moskowitz & Sharma, 1974), restrict visual scanning to central and salient image features (e.g., Harvey, 2014; Harvey, Kneller & Campbell, 2013a; Moser, Heide and Kömpf, 1998), impair memory for peripheral stimuli (Harvey et al.; 2013a; Schreiber Compo, Evans, Carol, et al., 2011), yet leave the identification of faces (typically, highly relevant stimuli) unimpaired (Harvey, 2014; Harvey, Kneller & Campbell, 2013b).

Posner (1980) used the analogy of a "spotlight" to describe the purely cognitive orienting of attention, the "beam" of which may be shifted to different spatial locations independently of eye movements, and research by Canto-Pereira et al. (2007, Experiment 1) suggests that even moderate doses of alcohol may restrict the spotlight's scope. Participants in this study responded to targets presented over a large visual area, either while focusing on a small square frame presented in the centre of a display screen or when instructed to distribute attention more widely, to each of two laterally situated frames. In the latter condition, sober controls were significantly faster than intoxicated counterparts at responding to peripheral stimulus targets, suggesting that alcohol restricts the field of visual attention tightly around

the point of gaze, even when participants are explicitly instructed to distribute it more widely. The present study sought to extend this work by employing a technique, developed by LaBerge (1983), designed to measure the extent of attention in the visual field. Laberge (1983) asserted that the scope of the attentional spotlight varies with the apparent size of the stimulus viewed, hence, attending to the central feature of a stimulus array (e.g., the nose of a face) requires a narrower spotlight than that required to attend to the full array (e.g., an entire face). Furthermore, a narrowed attentional spotlight should be less effective at capturing stimulus objects appearing in peripheral regions of the visual field.

LaBerge (1983) tested this hypothesis by presenting participants with long sequences of five-letter nouns forming the basis of two categorization tasks, each designed to manipulate the width of the attentional beam. In one task participants had to focus on the central letter of each word (narrow beam), responding as quickly as possible each time this letter was in the range A-G. For the other, they were required to categorize the entire word on each trial (wide beam) by responding only when the noun was a common name (e.g., “ALICE”, “ROGER”, etc.). In both tasks a number of words in each sequence were interpolated with a probe trial in which an uncued target probe (the digit “7”) would appear in any of the five word letter positions. Hence, responses to non-central probes in the letter task required a shift in attention to the left or right while responses to central probes did not. LaBerge (1983) found that probe reaction times in the word task were consistently fast across all five letter positions, presumably because participants’ attention spanned the full breadth of each stimulus array. For the letter task, however, responses were fast for central probes but slowed linearly for those presented in left or right positions, delays presumed to reflect the shifting of the spotlight to non-central locations.

In the present study, Laberge’s (1983) paradigm is employed to quantify the extent to which alcohol narrows the scope of attention in the visual field. AMT predicts that alcohol

will facilitate the central narrowing required to complete the letter categorization task, but at the cost of a reduced attentional field around the small, central point of focus. Hence, intoxicated participants are expected to show significant delays when responding to non-central probes, particularly for those occupying the outermost letter positions, producing a more acute V-shaped RT function than that of sober controls. Due to its diminishment of attentional resources, alcohol intoxication was also expected to increase the rate of detection errors for non-central probes and slow probe response times overall.

Method

Participants. Sixty-two undergraduate students were offered either course credit or £10 for participation in the study. The sample consisted of 34 females and 28 males ranging in age from 18–63 years (M = 23.53 years; SD = 7.78).

Design. The study conformed to a 2(Treatment: Alcohol vs. Placebo) × 2(Categorization Task: Letter vs. Word) × 5(Probe Position: 1-5) mixed-design, with reaction time (ms) and percentage of primary task and probe response errors serving as the dependent variables. Participants were randomly assigned to the placebo or alcohol condition.

Apparatus and materials. Breath alcohol concentration (BrAC) in participants' deep lung air was recorded using a Dräger 6510 Alcotest Fuel Cell Breathalyzer, a professional evidential testing and screening device that is Type Approved by the UK Home Office and extensively used by the UK police force. The unit of alcohol measurement was grams of alcohol per 210 litres of breath (g/210L).

The presentation of trial events and the recording of responses were controlled by a desktop PC, using Superlab 5 Stimulus Presentation Software and a Cedrus RB-834 response pad. Stimuli were presented on a 17-inch (338mm x 270mm) Belnea 1745S1 LCD monitor with a screen resolution of 1280 × 1024 pixels. Each participant was positioned on a height

adjustable chair with their eyes positioned approximately 45cm from the centre of the display screen.

Each trial consisted of a horizontal array of five stimulus characters with each character occupying a 1.0cm (W) × 1.2cm (H) space. Each stimulus array was aligned in the centre of the screen and displayed in black 48pt Tahoma Regular font with all characters spaced 1.5cm apart from each other. Each array therefore spanned a width of approximately 11cm. A string of five "#" symbols was displayed alerting participants to each new trial, and the stimuli that followed this warning signal always consisted of a string of five characters displayed in the same locations as the warning symbols. Assuming a 45cm viewing distance, each stimulus letter subtended a visual angle of 1.53° vertically, and 1.27° horizontally. The space separating each character in the array was 1.91°. The full stimulus array therefore subtended a horizontal visual angle of approximately 14°.

The response pad was placed on a table between the participant and the screen on which only one large (28mm × 38mm) button was used. Participants were required to press this in response to each target word/letter/probe, and were required to withhold the button press for non-target stimuli.

Stimuli and trial types. Following LaBerge (1983), the experiment consisted of two tasks, word categorization and letter categorization. For each of these tasks the primary (target) stimuli consisted of five-letter nouns. Primary stimuli for the word task were familiar English names (e.g., ALICE, BRIAN) and non-target items were nouns from the common categories of furniture, musical instruments, and dwellings. For the letter task primary stimuli consisted of common nouns in which the middle letters were from the set A through G (e.g., GRAVE, SUGAR), while non-target items were words in which the middle letter was from the Set N through U (e.g., EARTH, MONEY). Each primary item appeared only once. In addition to primary trials, both tasks included probe trials consisting of four "+" signs and one

critical item, a 7, T, or Z, which appeared at random in one of the five positions of the display string. For these surprise catch trials, 7 was the target probe while T and Z served as non-target items.

Procedure. The experiment was advertised as an investigation of the impact of alcohol intoxication on visual perception. Prior to their arrival at the lab, participants completed an alcohol advisory and screening questionnaire confirming their eligibility to take part and reminding them not to drive to the lab. The questionnaire also contained a sentence requesting they not eat within the 3-hours prior to their lab appointment time. The screen was designed to exclude respondents under 18-years of age (UK legal age for alcohol consumption), contraindicated for alcohol on medical grounds and those who had not consumed at least 6 units of alcohol in a single sitting during the previous 3 months. This measure and all other facets of the study were approved by the host university's ethics committee, and the experiment was administered with full adherence to the British Psychological Society Code of Ethics and Conduct.

All participants were tested between 9am and 1pm. Upon arrival at the lab each participant was breathalyzed to confirm an initial BrAC of zero and weighed to determine the size of their alcohol dose. Those in the alcohol group received a 500ml drink containing 1ml of ethanol per kg of body weight mixed with sugar free Indian tonic water. Those in the placebo group were served 500ml of Indian tonic water with traces of ethanol dropped on to the surface of the drink and mist-sprayed over the entire glass to produce a strong odour of alcohol, at least for the first few sips of the drink. Participants consumed their beverages within 15-20 minutes then read magazines for the next 30-minutes while the ethanol metabolized. After this rest period they rinsed their mouths with water to remove residual alcohol traces and gave a second BrAC recording. None were informed of their BrAC level until debrief. After the second breath test participants were asked to report their subjective

level of intoxication recorded on a 10-point scale (1 = "*completely sober*"; 10 = "*extremely drunk*") and were then escorted to the PC running the two experimental tasks. Participants were tested individually.

For both tasks, testing consisted of a practice block followed by a test block. Each trial was preceded by the warning signal described above, which was displayed for 1,250ms. This was followed by either a primary or probe stimulus trial, each of which remained visible until participants responded, up to a maximum of 1,500ms. The inter-trial interval showed a blank screen for 750ms. The practice block for each task consisted of 50 trials comprised of 20 probe trials, 20 primary stimulus target trials, and 10 primary stimulus non-target trials. For the word task, participants were told to respond when the primary display was the name of a person. For the letter task, they were told only to respond when the middle letter of the primary display was from the set A through G, and to treat the probe stimuli as they had for the word task. For both tasks, each practice trial was followed by two 80-trial test blocks each comprising 45 target primary stimulus trials, 15 non-target primary stimulus trials, and 20 probe trials. For probe trials, the positive item 7 appeared three times in each of the possible five positions. Participants were encouraged to respond as quickly and accurately as possible.

Together, the two categorization tasks took each participant approximately 30 minutes to complete, after which they were debriefed as to the full aims of the study. Those in the placebo group left the lab, but intoxicated participants were strongly encouraged to sit comfortably in a room adjacent to the lab, with free access to magazines and soft drink facilities, until their BrAC fell below 0.08g/210L (i.e., the legal UK driving limit). Those wishing to leave with a BrAC close to or over the legal driving limit were required to sign a disclaimer form confirming their awareness of this. The form also stated the associated risks of intoxication for driving, cycling or operating any other potentially dangerous machinery. It should be noted that participants were students of a residential University campus in a small

English town, the majority of whom lived only a short walk from the Department of Psychology. Nevertheless, all were informed of their BrAC immediately prior to departure.

Results

Intoxication levels. The amount of ethanol administered to participants in the alcohol condition ranged from 47ml to 105ml (M = 74ml; SD = 14) leading to a BrAC range of 0.04 to 0.11g/210L (M = 0.08g/210L; SD = 0.02). All BrAC measures for the placebo condition were zero. Subjective intoxication ratings taken immediately prior to the experimental task ranged from 1 to 7 (out of 10) (M = 2.37; SD = 1.56) for the placebo group, and 2 to 8 (M = 5.48, SD = 1.65) for the alcohol group. A Mann-Whitney U test confirmed participants in the alcohol group reported feeling significantly more intoxicated than those in the placebo group, $z = 5.53$, N = 62, $p < .001$. The higher subjective ratings of the alcohol group may therefore reflect a stronger expectation of poor performance relative to the placebo control group.

Reaction times for correct probe responses. Average reaction times for correct responses to probe stimuli are shown in Figure 1 as a function of task, alcohol treatment and probe position. In addition to probe position, the X-axis also displays the degrees of visual angle from the mid-point of the central probe to the mid-point of each of the four lateral probes. The RT data are based on an overall average of 154 (SD = 10.1) correct categorization and probe detection responses. A 2(Treatment) × 2(Task) × 5(Probe), mixed-design ANOVA was used to analyse differences in probe detection times between conditions. Prior to conducting this test, however, it was necessary to perform a logarithmic transformation on these data to obtain homogeneity of variance between treatment groups, although untransformed means are reported in Figure 1.

(Figure 1 about here)

Reaction times for correct probe responses were significantly faster for the word task (M = 591.90ms, SD = 11.09) than the letter task (M = 620.74ms, SD = 11.51), $F(1, 60) = 16.43$, $MSE = .07$, $p < .001$, $\eta_p^2 = .22$. Overall, probe response times varied significantly as a function of probe position, $F(3.64, 218.47) = 5.63$, $MSE = .01$, $p < .001$, $\eta_p^2 = .09$ (Huynh-Feldt corrected for non-sphericity) and the main source of this variance was the letter task, producing a highly significant Task × Probe interaction, $F(3.49, 209.46) = 18.91$, $MSE = .002$, $p < .001$, $\eta_p^2 = .24$ (Huynh-Feldt corrected for non-sphericity).

With regard to the effects of alcohol, intoxicated participants showed the expected slowing in RT for correct probe responses (M = 634.65ms, SD = 15.04), relative to sober controls (M = 577.99ms, SD = 15.04), $F(1, 60) = 7.44$, $MSE = .03$, $p < .008$, $\eta_p^2 = .11$. However, this treatment effect did not interact with the task variable, $F(1, 60) = .74$, $MSE = .004$, $p < .393$, $\eta_p^2 = .01$.

Of critical interest are the combined effects of alcohol intoxication and probe position on reaction times for correct probe responses, as shown in Figure 1. For the letter task, differences in mean correct probe response times between intoxicated and control participants for probe positions 1-5 were: 59.27ms, 55.42ms, 34.03ms (central position), 78.58ms and 100.62ms, respectively; whereas in the word task, alcohol-placebo RT differences for probe positions 1-5 were: 51.83ms, 57.09ms, 65.76ms (central position), 37.44ms and 26.61ms, respectively. The ANOVA revealed the interaction between alcohol treatment, task and probe position to be highly significant, $F(3.49, 209.46) = 3.21$, $MSE = .002$, $p = .018$, $\eta_p^2 = .05$ (Huynh-Feldt corrected for non-sphericity). As expected, a post hoc two-way ANOVA conducted on correct probe RTs for the word task confirmed that the Treatment × Probe Position interaction was non-significant, $F(2.81, 168.53) = .80$, $MSE = 6765.24$, $p = .488$, $\eta_p^2 = .01$ (Huynh-Feldt corrected for non-sphericity). Contrary to predictions, though, the

Treatment × Probe Position interaction for the letter task was also non-significant, $F(4, 240) = 2.39$, $MSE = .002$, $p = .051$, $\eta_p^2 = .04$ (Huynh-Feldt corrected for non-sphericity, and log transformed to homogenize variance). However, post-hoc independent-samples t-tests comparing mean probe RTs between the alcohol group and placebo controls at each probe position of the letter task revealed the expected pattern of findings: no significant difference at (central) probe position 3 ($p = .258$, $d = .29$), but significant differences at positions 1 ($p = .034$, $d = .56$), 2 ($p = .025$, $d = .59$), 4 ($p = .008$, $d = .71$) and 5 ($p < .001$, $d = 1.09$). For the word task, on the other hand, differences at probe positions 1 ($p = .026$, $d = .59$) and 2 ($p = .037$, $d = .55$) were significant, but those at positions 3 ($p = .101$, $d = .43$), 4 ($p = .133$, $d = .39$) and 5 ($p = .229$, $d = .31$) were not.

Probe response and categorization errors. The overall error rate across both tasks was 3.8% and of these trials only 6 were probe detection errors. All errors were made by the alcohol group for non-central probes (3 from the word task and 3 from the letter task). These data are obviously too scanty for inferential analysis.

The mean rate of letter categorization errors was 2.20% (SD = 3.65) for the placebo group, and 3.47% (SD = 3.72) for the alcohol group, $t(60) = 1.36$, $p = .178$, $r^2 = 0.03$. For the word task, the average categorization error rate was 3.37% (SD = 2.98) for the placebo group, and 7.62% (SD = 9.84) for the alcohol group, $t(60) = 2.30$, $p = .025$, $r^2 = 0.08$.

Discussion

The main finding of this study is that in the letter categorization task, which required attention to remain focused on the central character of each stimulus word, alcohol slowed correct responses to surprise probes presented in non-central character positions. Sober controls took an average of 27ms per character space to shift attention from central to non-central letter positions, whereas the alcohol group took almost twice as long, with a mean

shift duration of 49ms per character space. While a small effect (η_p^2 =.04) that is just shy of statistical significance (p = .051), the interaction between probe position and alcohol treatment shown for the letter task is nevertheless larger than that shown for the word task (η_p^2 =.01) and of a form predicted by alcohol myopia theory. Furthermore, post-hoc comparisons of probe RTs between the alcohol and control group at each probe position show that, in the letter task, alcohol significantly slowed correct responses to lateral but not central probes. Only when focal attention was widened, for the word task, was alcohol found to significantly slow responses to centrally positioned probes.

The present findings should be compared to those of Canto-Pereira et al. (2007) whose intoxicated participants had difficulty dividing attention between two lateral regions of the visual field, making significantly slower responses than sober controls to lateral visual targets. In interpreting their findings these authors concluded that the visual attention of intoxicated viewers is tightly and inflexibly focused around the point of gaze, relative to that of sober controls. But, according to the present data, intoxicated viewers are able to vary the scope of a single attentional spotlight in accordance with central task demands. When the task requires them to "zoom-in" on a small central stimulus feature or region, however, the extent of the attentional field around this focal point is narrowed, thus slowing responses to lateral probes relative to sober controls. It is also possible that the narrower spotlight of intoxicated participants fosters a slower serial search for lateral probe targets, whereas the wider attentional field of sober viewers permits a more efficient parallel search.

In the word task, on the other hand, for which the spotlight on each trial is widened to process the full stimulus array, alcohol caused less variation in response latencies across probe positions; although the drug did produce an overall slowing in probe detection times. This was expected, however, and is assumed to reflect the general sedative effect of alcohol on the central nervous system, leading to the depletion of central processing capacity (e.g.,

Maylor, Rabbit, James & Kerr, 1990; Rohrbaugh, Stapleton, Parasuraman, & Frowein, 1988).

Despite the present study's support for alcohol myopia, there remain three unexpected aspects of the data that warrant discussion. Firstly, on the basis of the spotlight-narrowing account of AMT, an increase in the rate of recognition errors for non-central probes in the letter task was predicted, but these mistakes rarely occurred. Therefore, with fewer information processing resources at their disposal, intoxicated viewers may have traded probe-response speed for probe-detection accuracy.

The second unexpected observation is the asymmetric effect of alcohol intoxication on correct response latencies for letter task probes. Why alcohol slowed responses for right-side more than left-side probes is unclear, but it is perhaps a consequence of the verbal categorization stimuli. It is possible that participants' bias for left-to-right word reading caused anticipatory leftward shifts in attention to the first letter position prior to each new trial, thus increasing the length of the rightward shift required for surprise right-field probe presentations for which the alcohol group were expected to show delays. Alternatively, faster responses to leftfield probes may reflect a global visuospatial attentional bias. It is of interest to note that, in the line bisection task, normal sober viewers systematically misperceive the midpoint of horizontal lines as being left of veridical centre, which is assumed to reflect a universal neglect of visual attention to right hemispace (e.g., Sosa, Teder-Sälejärvi & McCourt, 2010). Under the influence of alcohol, however, this leftward bias is exaggerated, suggesting that ethanol exerts an asymmetric effect on the brain with increased suppression of left as opposed to right hemisphere function (Leone & McCourt, 2010). It should be added, though, that this interpretation is inconsistent with earlier evidence of alcohol selectively depressing right-hemisphere functioning (e.g., Rhodes, Obitz & Creel, 1975; Kostandov et al., 1982).

The final unexpected outcome of the present study is the different RT function shown

between the alcohol group and sober controls during letter categorization. On the basis of the Laberge (1983, Experiment 1) data, both treatment groups were expected to produce a V-shaped function for the letter task, reflecting a spotlight narrowly trained on the central character of each stimulus word, with the V-angle for the alcohol group expected to be more acute in form. However, only intoxicated participants produced the V-function. The letter task probe response function for sober controls was U-shaped, suggesting that this group's attentional spotlight extended beyond the central character position. This contrast may be accounted for by differences in the dimensions of the stimuli in the present study compared to that of Laberge (1983). In the latter study, the horizontal visual angle for a single character was small (29°) relative to the present experiment (1.27°), while viewing distances in both studies were comparable (approx. 44-45cm).

It should also be noted that the spotlight-narrowing account of the present alcohol data is based on Laberge's (1983) assumption that probe response delays in the letter task reflect increases in the distance attention is shifted from central to lateral positions. However, should probe detection be supported by gaze shifts, then it is possible that alcohol slowed eye movements to non-central letter positions. Unfortunately, the absence of eye movement monitoring in the present study means that this interpretation cannot be ruled-out, and it is a view supported by numerous studies in which alcohol is shown to slow saccadic function (e.g., Holdstock & de Wit, 1999; Moser, Heide, & Kompf, 1998; Nawrot, Nordenstrom, & Olson, 2003; Wilkinson, 1976).

A further limitation of the present study concerns the nature of the word- and letter-categorization tasks used to manipulate the scope of the attentional spotlight. The discriminations and decision making processes required to categorize letters are likely quite different to those used to categorize words, hence, differences between these tasks may have cast undue influences on probe RT data. Further work is therefore required to determine if the

present findings extend to studies in which the primary task is not only non-verbal, but also matched under narrow- and wide-scope attentional conditions.

Finally, the spotlight and zoom-lens accounts of visual attention are limited to situations in which a single attentional "beam" is directed toward one particular region of the visual field, but there is evidence to suggest that attention is primarily driven by the selection of objects rather than spatial locations (Emmanouil & Magen, 2014). Studies of object-based attention demonstrate that visual attention can be effectively distributed across different spatial regions when those locations are occupied by the same object, emphasising viewing conditions for which the single "spotlight" account is clearly inadequate (e.g., Duncan, 1984; O'Craven, Downing, & Kanwisher, 1999). It should therefore be noted that the location-based account offered here is for data drawn from tasks in which stimulus objects and their spatial locations are confounded.

In conclusion, the present study nevertheless demonstrates a significant attentional deficit resulting from only moderate alcohol intoxication (mean BAC ≈ .08%). Namely, a narrowing in the scope of visual attention around a central focal point, which almost doubles the time taken to respond to surprise peripheral targets.

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Figure 1. Mean reaction time (ms) for correct probe responses as a function of task, probe position, visual angle from central probe and alcohol treatment. Error bars show ± 1 SE of the mean.