The Impact of Alcohol Intoxication on Extended Vigilance and Rest-Break Recovery

Runhan Yang, Trisha N. Patel, Catharine E. Fairbairn, and Aaron S. Benjamin
University of Illinois Urbana-Champaign

Abstract

Alcohol has complex and multifarious effects on cognition. One means by which alcohol can influence a wide variety of cognitive behaviors is through its effects on attention. This study investigated the effects of alcohol consumption on sustained attention, or *vigilance*. We report here a high-powered study in which participants consumed either an alcoholic or a non-alcoholic beverage and then completed a spatial vigilance task, with half of the subjects in each condition receiving two rest breaks interleaved throughout the task. Alcohol impaired vigilance performance and also decreased the local recuperative benefit of rest breaks. Difference in decision processes were apparent, with intoxicated participants employing a more liberal and less optimal response criterion. These findings underscore the detrimental effects of alcohol on attention and provide novel evidence that rest is less effective following alcohol consumption.

Keywords: sustained attention, vigilance, alcohol, Signal Detection Theory

Open Practices Statement

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Code Availability: All analysis scripts are publicly available in OSF repository, https://osf.io/34ex5/.
Correspondence concerning this article should be addressed to Runhan Yang, Department of Psychology, University of Illinois Urbana-Champaign. E-mail: runhany2@illinois.edu.
https://orcid.org/0009-0007-9239-0673

Declarations

Conceptualization: Trisha N. Patel, Catharine E. Fairbairn, and Aaron S. Benjamin.

Data curation: Runhan Yang, Trisha N. Patel, and Catharine E. Fairbairn.

Formal analysis: Runhan Yang.

Funding acquisition: Catharine E. Fairbairn.

Investigation: Trisha N. Patel.

Methodology: Trisha N. Patel.

Project administration: Catharine E. Fairbairn, and Aaron S. Benjamin.

Resources: Catharine E. Fairbairn.

Software: Runhan Yang and Trisha N. Patel.

Supervision: Catharine E. Fairbairn and Aaron S. Benjamin.

Visualization: Runhan Yang.

Writing - original draft: Runhan Yang, and Trisha N. Patel.

Writing - review editing: Runhan Yang, Catharine E. Fairbairn, and Aaron S. Benjamin.

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Sustained attention, or *vigilance*, refers to the ability to maintain focus on task-relevant information for a prolonged period of time. Failures of vigilance can lead to unmet deadlines and incomplete work. It can also have more serious immediate consequences for oneself and others when driving, as evidenced by the massive influence of distraction on highway accidents (Sajid Hasan et al., 2022). Many factors affect the quality of sustained attention, including age (Carriere et al., 2010), time of day (Riley et al., 2017), mental health (Valentine & Sweet, 1999), and the presence of distraction (Demeter et al., 2011). Here we evaluate the effect of alcohol consumption on sustained attention, as well as on the extent to which short rest breaks differentially allow for the recovery of performance in sober and intoxicated subjects.

The societal effects of alcohol on human flourishing are complex. It is common for artists and writers to report inspiration from alcohol. One of the most famous ancient Chinese poets, Li Bai (also known as Wine Immortal), created many of his literary works with inspiration from wine (Kwong, 2013). But alcohol misuse also causes many physical, mental, and social problems, including liver disease (Becker et al., 1996), poor cardiovascular health (Klatsky, 2010), depression (Boden & Fergusson, 2011), and anxiety (Kushner et al., 1990)). Research on basic, low-level, cognitive functions like attention holds some promise in piecing together a coherent theory of the myriad ways in which alcohol affects perception, attention, and memory and how those basic skills translate into real-world behavior.

An important lesson from the literature on the psychological effects of alcohol is that effects are task- and dose-dependent. Breitmeier et al. (2007) found that a low Blood Alcohol Concentration (BAC) of around 0.03% significantly impaired vigilance for acoustic but not for visual stimuli. Effects on cognition may even be nonmonotonic: Benedek et al. (2017) reported beneficial effects of alcohol at a BAC of 0.03% on a common test for measuring creativity. At higher doses, the effect of alcohol is more deleterious, and broadly so. Jongen et al. (2014) found that BAC levels of 0.05% and 0.08% impaired both a psychomotor vigilance test and a divided attention task. These high BAC levels also lead to antisocial behavior in the form of hostile verbal interactions (Babor et al., 1983) and violence (Rossow, 1996).

One perspective on these and other findings is provided by *alcohol myopia theory*, which proposes that alcohol narrows cognitive and perceptual processes and causes short-sighted decision-making (Steele & Josephs, 1990). Alcohol myopia leads people to downweight the long-term consequences of their behaviors and to prioritize immediate pleasure or emotional release that can cause distraction. The consequences of such behavior can be beneficial or dangerous. For example, individuals under the influence of alcohol are more altruistic (Steele et al., 1985) and more willing to form closer relationships (Gurrieri et al., 2021), but can also be hostile during interactions with strangers (Babor et al., 1983).

Alcohol myopia theory is closely related to the concept of *disinhibition*. Disinhibition refers to an inability to control impulses, and is thought to arise from a narrowed cognitive focus. Disinhibition can be seen at both a macroscopic level in the types of social interactions reviewed above, and also on very simple measures of perception and cognition. Rose and Duka (2007) administered a moderate dose of alcohol to participants and had them perform a motor (go/no-go; GNG) task or a cognitive control (Stroop) task. In the GNG task, participants were instructed to press the space bar whenever they saw a vertical indicator on the screen and to avoid pressing the space bar when the indicator was tilted. Because the indicators were mostly vertical, the task encouraged habitual responding. In both tasks, participants intoxicated with alcohol responded more quickly and made more errors, indicating less careful scrutiny of stimuli and a stronger effect of disinhibition. Disinhibition has obvious negative consequences but may also underlie the sense of relaxation of standards that enhances creativity (Vartanian, 2002) and related skills.

In tasks of discrimination and detection, it is important to draw a distinction between the *discriminal processes* that underlie decisions and the decision processes, or *response bias*, that accompany the translation of that information into a response (Green & Swets, 1966). This distinction is particularly relevant in understanding the effects of alcohol, because alcohol can affect the quality of the information that is educed from one's environment or from memory, and it can also affect the standards we set for ourselves for translating that evidence into a response. Both effects can be simply and effectively measured using Signal Detection Theory (SDT; Wickens, 2001). The basic assumptions of the theory are that evidence is stochastic, and that decisions are made by comparing noisy evidence to a decision criterion (cf. Benjamin et al., 2009). It is important to be able to differentiate between discriminability and response bias in a sustained attention task, because it is easy to mistake the effects of one for the other (McCarley & Yamani, 2021; Thomson et al., 2016). The use of SDT provides another major benefit for the comparison of groups: measures of discriminability that derive from SDT have simple analogues in Euclidean geometry and so can be treated as existing on an interval scale of measurement. This makes it possible to interpret non-disordinal interactions, which are common in the comparison of groups and often confound interpretation (cf. Loftus, 1978; Wagenmakers et al., 2012). Such interactions are widely evident in the alcohol literature (e.g., Maylor & Rabbitt, 1987; Maylor et al., 1987).

Previous studies that examined the effects of alcohol on discrimination using SDT have consistently found that it leads to decreased sensitivity. In one study by Rohrbaugh et al. (1988) who investigated the alcohol effect on sustained attention, participants viewed a rapid series of digits and were required to respond only to the target digit "0." Results showed that alcohol had two effects: it decreased discriminability—that is, the quality of the perceptual information that subjects brought to the decision—and also decreased response bias, by leading to more positive responding, even with minimal evidence. This general effect of diminished sensitivity for intoxicated individuals has been widely replicated (e.g., Jansen et al., 1985; Schneider & Carpenter, 1969; Wright & Mikkonen, 1970).

The effects of alcohol on decision processes (i.e., response bias) are straightforwardly relatable to disinhibition, but empirical evidence is somewhat mixed. Jansen et al. (1985) conducted a signal detection task in which participants were required to discriminate between two movement patterns. A dot jumped among a 10×10 matrix of circles and skipped either one or two circles at a time. The dot that skipped only one circle at a time was designated to be the target. Comparisons between participants with a moderate BAC level (0.7 g/kg) and sober participants indicated no clear effect of alcohol on criterion placement. In another study by Wright and Mikkonen (1970), participants were instructed to detect an auditory signal of 1000Hz from noise. In this task, intoxicated participants actually exhibited more *conservative* responding. Similar results were reported by Schneider and Carpenter (1969) and Timney et al. (2016). All of these studies used a relatively small sample size (<20), rendering clear conclusions about the effects of alcohol on criterion challenging.

Fatigue and rest are a major determinant of performance on attention-demanding tasks. Decreases in attention over time are sometimes characterized as *vigilance decrements*, which can be alleviated by breaks (Helton & Russell, 2015). Longer-term recovery through ample sleep also enhances performance (Debus et al., 2014; Lim & Dinges, 2008). Though there is extensive literature examining the effects of alcohol on attention, there have been no studies to date that also examine the benefits of rest on recovery under conditions of alcohol intoxication. There are studies that examine the interactive effects of alcohol with other variables that might be thought of as affecting one's overall "cognitive state," including practice (Maylor & Rabbitt, 1987), task difficulty (Lewis, 1973), and disruptive ambient noise (Colquhoun & Edwards, 1975). These studies may be suggestive as to the ways in which the benefits of rest differ following alcohol intoxication.

Colquhoun and Edwards (1975) found that alcohol impaired sustained attention performance on a visual response time task when background audio noise was at a low volume but actually improved performance when the noise was at a high volume. Maylor and Rabbitt (1987) showed that the benefit of practice was greater with alcohol than without—a result that was at least partially due to the fact that the performance of subjects who consumed alcohol was initially lower, leaving more room for the benefit of practice to reveal itself. Lewis (1973) found that alcohol impaired performance on a set of difficult cognitive tests but not on easy ones.

The notion that alcohol may have salutary effects on cognition is an appealing one, given the widespread popularity of alcohol in many cultures. The anecdotal reports of enhancements to creativity and the reports reviewed here in which alcohol appears to enhance or minimally disrupt cognition make such an outcome worth considering. However, it is also worth remembering that historical studies of alcohol and cognition often have small sample sizes and low power, making the outcomes unreliable (Stanley et al., 2018). In the study reported here, we use a large sample size to ensure that the effects we see of alcohol on attention and on recovery from rest breaks are replicable.

The impact of alcohol and rest breaks on vigilance has a crucial real-world application—drunk driving. In 2021, about 37 people in the US died in drunk-driving accidents per day—that is, about 1 death every 39 minutes (Stewart, 2023). Alcohol myopia and disinhibition may lead individuals to ignore or downplay the influence of alcohol on vigilance when they decide to drive drunk (Bornewasser & Glitsch, 2000). A report by MacDonald et al. (1995) is informative here. They elicited beliefs and self-assessments about drunk driving from both sober and intoxicated participants. For statements that had a neutral tone (e.g, “I will drink and drive the next time I am at a party or bar.”), both groups were equally negative about drunk driving. However, for statements that include an impelling reason (e.g., “If I only had a short distance to drive, I would drive while intoxicated.”), intoxicated participants expressed less negative views about the behavior. This type of rationalization may also lead intoxicated individuals to feel that short breaks will help offset any impairment from alcohol. To our knowledge, no prior research has examined the effect of breaks on vigilance in intoxicated individuals.

The present study aims to precisely measure the consequences of alcohol intoxication and of short rest breaks on a well-validated vigilance task using a measurement tool that enables the separation of discriminal and decision processes.

For the purpose of the study, participants first went through the beverage administration phase in which half were given an alcoholic beverage and the other half were given a nonalcoholic beverage. Both groups then completed a spatial vigilance task; half of the subjects in each group received two breaks during the task and the other half did not.

Methods

Participants

A total of 246 (average age = 22.04 years old, 56.1% female) participants ages 21 to 30 took part in this study and were monetarily compensated for their time. 52% of the participants identified themselves as White, 20% as Asian, 7% as Black, and the remaining as other ethnicity. Seven participants were excluded due to technical issues. They were recruited through a mix of the following approaches: flyers posted in the local community (supermarkets, restaurants, bars, and housing developments), flyers distributed in person outside local bars and restaurants, social media posts, and mass University email announcements.

A sensitivity analysis was conducted using G*Power (version 3.1.9.7; Faul et al., 2007). For a between-subjects t-test, an effect of d = 0.5 has power of 0.97 at $\alpha = 0.05$. Even for a mixed-effect ANOVA at the very small effect size of f = 0.1, power = 0.87. These values indicate ample power to detect basic group effects (for which d = 0.5 is a conservative estimate) and post-hoc effects based on data restrictions (introduced below) that will have larger variability.

Procedure and Task

This experiment implemented a 2 (alcoholic vs. control nonalcoholic beverage) x 2 (breaks vs. no breaks) between-subjects design. Participants were randomly assigned to one of the four conditions.

Upon arriving, participants' height, weight and breath alcohol concentration (BrAC) was measured. After confirming a BrAC of 0.00%, participants signed the consent form and completed various baseline self-report assessments. They then completed the beverage administration phase and the vigilance task. Note that the beverage administration phase was part of a broader study examining the effects of social contextual factors on responses to alcohol. The details of this parent study are not relevant to the current study and are not reported here. All protocols and procedures were approved by the Institutional Review Board (IRB) at University of Illinois Urbana-Champaign.

Beverage Administration. Participants in the alcohol condition received a beverage containing a moderate dose of alcohol meant to achieve a peak BrAC of 0.08%. The precise amount of alcohol administered was adjusted based on gender, height, age, and weight (the formula can be found in Watson et al., 1981). Those in the control condition were provided with a nonalcoholic beverage and the amount administered was calculated in the same manner as for those in the alcohol condition.

Note that, since this task occurred as part of a larger study, beverages were consumed in a dyadic setting and administered in three equal parts over 36 minutes. We employed a control rather than a placebo condition. Unanticipated compensatory reactions have been documented in studies featuring social contexts and placebo manipulations, such that it is unclear whether the placebo manipulation effectively isolates expectancy effects in the manner intended. Also, since this study ultimately aims to mirror real-world drinking situations in which individuals will not be routinely unaware of the contents of their beverages, we opted to use no deception in the control condition of the current study (Fairbairn et al., 2015; Testa et al., 2006).

Once this phase was completed, BrACs were collected. A subset of study participants (n = 44; n = 22 alcohol condition) underwent an approximate 65-minute absorption period post-drink (see also the Results section and footnote[1]). The

[1] At the outset of the study, we randomly assigned equal numbers of participants into the immediate and

manipulation was due to the design of another study in the larger dataset. The beverage-manipulation check in the later section showed that the difference in timing did not affect the intoxication level in the vigilance task. Other articles published using the dataset (Ariss et al., 2023; Gurrieri et al., 2021; Kang et al., 2022) have not examined the effect of alcohol on vigilance using the data from the vigilance task.

Vigilance Task. Participants conducted a spatial vigilance task that has been found to produce a rapid decrement within a short amount of time (Helton & Russell, 2015; Patel et al., 2024). In this task, participants were first instructed to focus on a black fixation cross that appeared in the center of the light gray screen. A small oval appeared to the left or right of the fixation cross with equal probability and remained on the screen for 200ms. A majority of these ovals were "near" ovals, appearing 20mm away from the fixation cross. However, approximately 18% of the time, a "far" oval was presented. Far ovals were placed 25mm from the fixation cross and were designated as target events. When participants noticed a target event, they were instructed to respond quickly by pressing the space bar. Subjects were instructed not to press the space bar following "near" ovals.

From the onset of the oval, participants had a total of 1200ms to respond before the next trial started. The task consisted of 6 blocks, each consisting of 44 trials (36 non-target trials and 8 target trials). Participants were unaware of the underlying block structure. Those in the break condition were given a 30 sec break after the 2nd and 4th block. During the break, participants viewed a countdown of the time remaining. Those who were not in the break condition continued with the task without any interruptions.

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delay conditions. However, in the latter half of the study, we prioritized capturing participant responses on the ascending limb of the BrAC curve, resulting in the imbalance of sample size between the immediate (n = 202) versus delay condition (n = 44). See Results for comparative BrAC levels across these two subgroups.

Results

Data analyses were conducted in R (version 4.2.1; R Core Team, 2023). Data and analysis codes are available at https://osf.io/34ex5/.

We used Welch's t-test for comparing between-subjects data (Delacre et al., 2017). Degrees of freedom were approximated using Welch-Satterthwaite equation (R Core Team, 2023; Welch, 1947). We also conducted Bayesian Analyses of Variance (ANOVA) in JASP (version 0.18.1; JASP Team, 2023). Bayes Factors of greater than 3.0 are considered to offer substantial support for the alternative hypothesis and Bayes Factors of less than 0.3 are taken to provide substantial support for the null hypothesis. Note that Bayes Factors standard of 3.0 is substantially more conservative than the traditional $\alpha < .05$ criterion used in null hypothesis significance testing (NHST). A Bayes Factor of 1 - 3 is interpreted to provide anecdotal evidence for the alternative hypothesis (Jeffreys, 1961) and is comparable to a α of 0.01 - 0.05 criterion in NHST (Jeon & De Boeck, 2017).

Beverage-manipulation check

Immediately following beverage administration, participants assigned to receive alcohol (n = 124) registered an average BrAC of 0.071% (SD = 0.017). Participants who engaged in the vigilance task immediately registered an average BrAC level of 0.081% (SD = 0.015; n = 102) and those who underwent the absorption period registered an average BrAC level of 0.073% (SD = 0.009, n = 22). Participants assigned to receive the control beverage registered 0.00% BrAC following beverage administration.

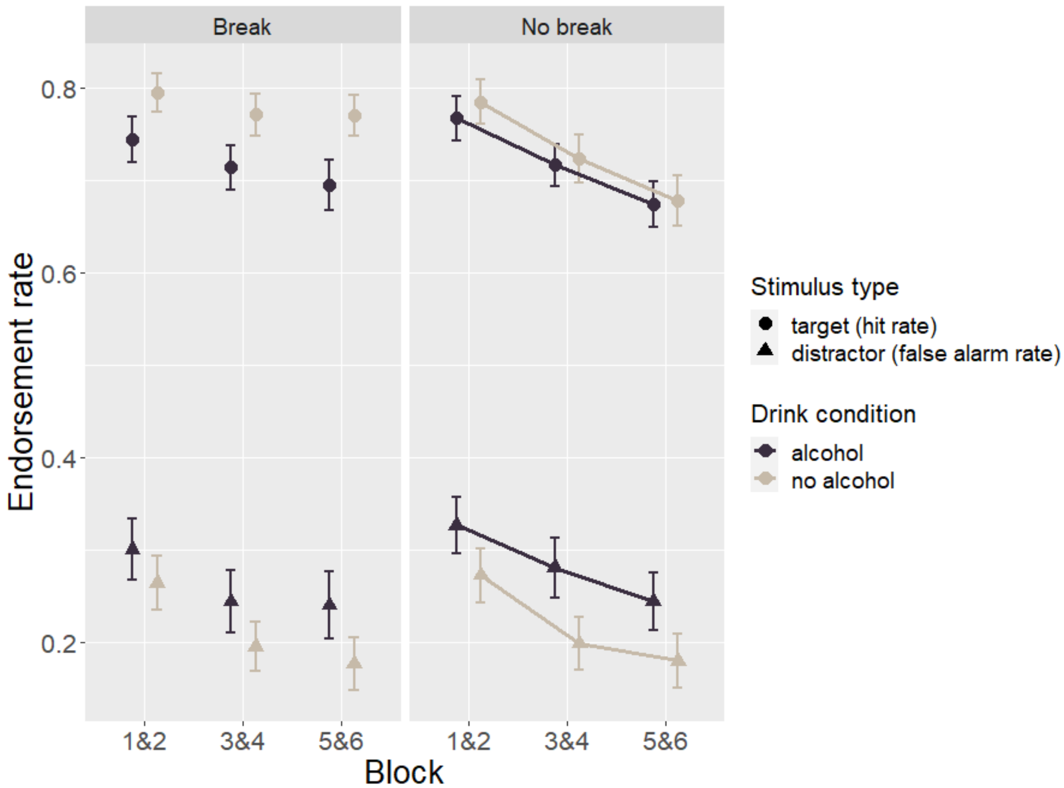
Hit and false-alarm rates

Figure 1 illustrates the hit rate (HR; the probability of correctly responding on target-present trials) and the false-alarm rate (FAR; the probability of incorrectly responding on target-absent trials) across the break and drink conditions. Higher hit rates and lower false alarm rates are evident in the no alcohol group. Both HR and FAR decreased over blocks.

The hit rate and false alarm rate reflect both discriminal processes and response

Figure 1

Hit rate and false alarm rate as a function of break and alcohol conditions

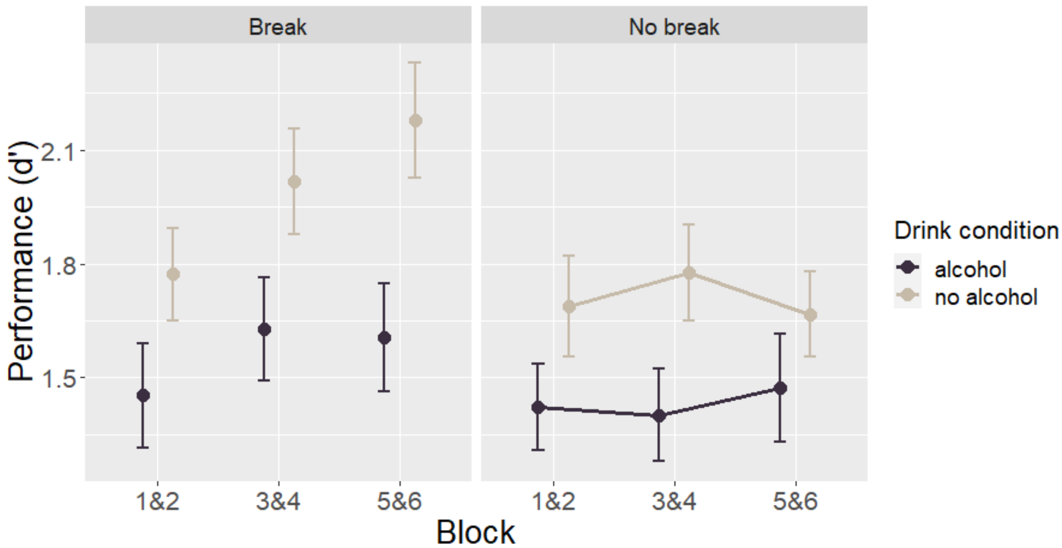


The left plot depicts the break condition and the right plot depicts the no break condition. The points are connected in the right plot to indicate the continuous experience of the subject and not connected in the left to indicate the breaks. Error bars represent ± 1 between-subjects standard error.

bias, rendering interpretation challenging without a model for teasing apart those effects (Thomson et al., 2016). For this reason we do not further analyze these statistics. Signal-detection theory provides a simple means of computing d', a measurement of sensitivity, and c, a measurement of response bias. d' is the standardized difference between hit rate and false alarm rate and c is the criterion by which individuals use to determine the presence of the target (Wickens, 2001), measured in units of standard deviation. Both measurements are parametric and are standard, well-validated ways of assessing sensitivity and response bias for yes/no discrimination tasks.

Figure 2

Discriminability (d') across break and alcohol conditions



Error bars represent ± 1 between-subjects standard error.

Discriminability

We conducted a 2 (alcohol vs. no alcohol) by 2 (break vs. no break) by 3 (block 1&2 vs. 3&4 vs. 5&6) mixed ANOVA with the first two factors between-subjects and the third within-subjects. The results are shown in Figure 2. Results revealed a main effect of drink condition (F(1,235) = 9.02, p = 0.003, $\eta^2 = 0.032$, $BF_{10} = 11.57$), a main effect of block (F(2,470) = 6.27, p = 0.002, $\eta^2 = 0.004$, $BF_{10} = 6.33$), and an interaction effect between break and block (F(2,470) = 4.92, p = 0.008, $\eta^2 = 0.003$, $BF_{10} = 17.26$) wherein the benefit of a break was greater in later blocks. No omnibus effect of break was identified (F(1,235) = 3.16, p = 0.077, $\eta^2 = 0.011$, $BF_{10} = 0.94$).

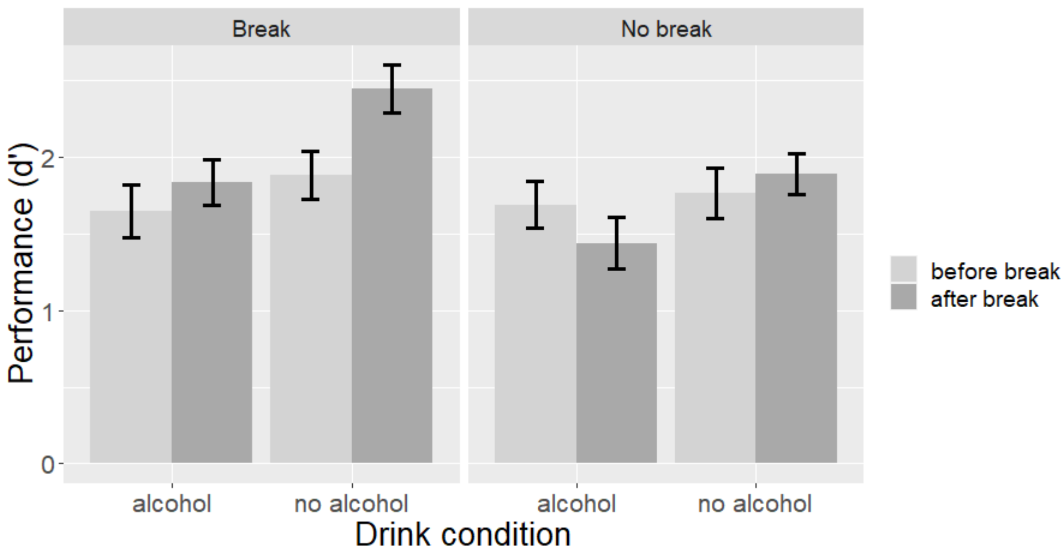
One possible reason for the unclear effect of breaks is that the benefits of breaks are immediate and local, and those benefits are not easily seen in an analysis that includes the full complement of trials (the large majority of which did not immediately follow a break). We conducted a more localized analysis by comparing the performance on the 20 trials immediately before and after each break in the break condition and the performance on the same trial numbers in the no break condition. This analysis was not pre-planned but was also conducted without having first examined the underlying descriptive effects of interest. The results are shown in Figure 3. A 2 (alcohol vs. no alcohol) by 2 (pre- vs. post-break) mixed ANOVA with alcohol as the between-subjects variable and pre-/post-break as the within-subjects variable revealed a main effect of alcohol (F(1,118) = 4.54, p = 0.035, η^2 = 0.030, BF_{10} = 1.70), a main effect of break (F(1,118) = 16.11, p < 0.001, η^2 = 0.025, BF_{10} = 172.53), and an interaction effect (F(1,118) = 4.13, p = 0.044, η^2 = 0.006, BF_{10} = 1.23) wherein the benefit of the break was greater for sober than intoxicated subjects. The same analysis was applied to the equivalent trial numbers in the no-break condition in order to confirm the absence of break effects in that condition. Results revealed no main effect of drink (F(1,117) = 2.18, p = 0.143, η^2 = 0.015, BF_{10} = 0.69), no main effect of break (F(1,117) = 0.49, p = 0.484, η^2 = 0.001, BF_{10} = 0.17), and an interaction between the two (F(1,117) = 4.01, p = 0.047, η^2 = 0.007, BF_{10} = 1.09). The ANOVA results in the break condition suggest that breaks improved performance and also that participants who did not drink alcohol benefited more from the breaks, at least immediately, than those who did drink alcohol. Note that, though the interaction effect in the no-break condition was significant, it was not in the same direction as in the break condition. Participants in the no-break condition did not experience a performance improvement.

Response bias analyses

We also analyzed the effects of break and alcohol on response bias. In SDT, c is used to describe the amount of evidence needed for an individual to report the presence of a target. Lower values of c indicate more liberal responding. A 2 (alcohol vs. no alcohol) by 2 (break vs. no break) between-subjects ANOVA detected a main effect of drink condition (F(1,235) = 4.15, p = 0.043, η^2 = 0.02, BF_{10} = 1.02), no effect of break condition (F(1,235) = 0.3, p = 0.583, η^2 = 0.001, BF_{10} = 0.163), and no interaction effect (F(1,235) = 0.038, p = 0.85, η^2 = 0.0001, BF_{10} = 0.18, Figure 4). A follow-up t-test

Figure 3

Performance immediately before and after each break



Each bar represents performance computed over the 20 trials before each break and 20 trials after each break in the break condition and the trials of the same trial number in the no break condition. Error bars represent ± 1 between-subjects standard error.

showed that sober participants exhibited more conservative responding (M = 0.97, SD = 0.82) than intoxicated subjects (M = 0.74, SD = 0.86, t(235.83) = 2.05, p = 0.042, η^2 = 0.02, BF_{10} = 1.02).

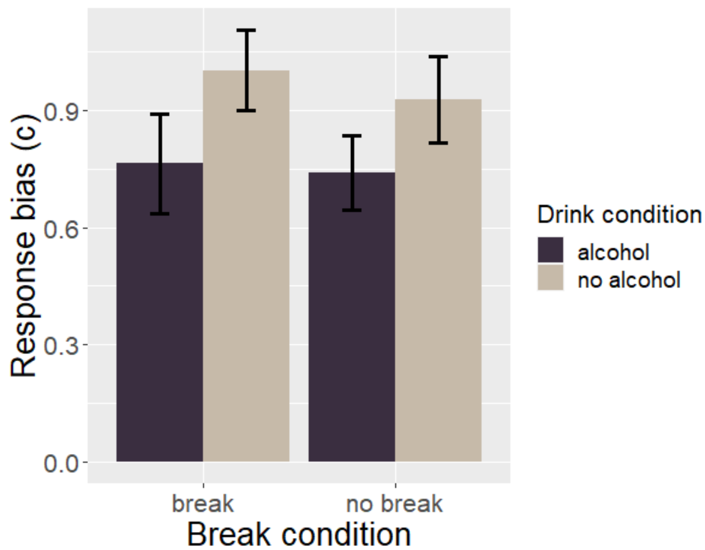
To examine the effects of block on response bias, we conducted a 2 (alcohol vs. no alcohol) by 2 (break vs. no break) by 3 (block 1&2 vs. 3&4 vs. 5&6) mixed ANOVA and found a main effect of block (F(2,470) = 82.04, p $<$ 0.001, $BF_{10} > 1000$). Participants tended towards more conservative responding with more time on task. The main effect of drink condition was no longer significant in the mixed ANOVA. This is likely due to the increased error variability when dividing the dataset into three blocks.

Discussion

In this paper, we evaluated the effects of alcohol on attention and on the benefit of breaks in maintaining vigilance. The work here employs methodological approaches that

Figure 4

Response bias comparison between break and alcohol conditions



Participants in the alcohol condition adopted a more liberal criterion. Error bars represent ± 1 between-subjects standard error.

are not always used in studies of alcohol and cognition, including a large sample size and the analytic tool of signal-detection theory. Several lessons are apparent.

A BrAC level of 0.08% impaired performance on this simple task of attention. A similar detrimental effect of alcohol can be found in previous studies that used the same high dose of alcohol (e.g, Dry et al., 2012; Jongen et al., 2014). In addition, participants who drank alcohol adopted a more liberal decision criterion for identifying the target, a result that is also in accordance with previous literature (e.g., Rohrbaugh et al., 1988).

The more liberal criterion placement by intoxicated participants likely reflects two factors. It is widely accepted that intoxicated individuals are *disinhibited*—that is, they exhibit greater difficulty in withholding contextually inapppropriate behaviors. In the context of target identification tasks, the magnitude of this disinhibition is reflected in the false-alarm rate. The result that intoxicated participants exhibited a higher false-alarm rate is in line with the well-known effect of alcohol consumption on disinhibited responding.

Similar effects of disinhibition are also found in research on social interaction. Research has shown that drinking can lead to closer (Gurrieri et al., 2021) or even more hostile interactions between strangers (Babor et al., 1983), riskier decision-making when gambling (Cronce & Corbin, 2010), and higher impulsivity in sexual behavior (Justus et al., 2000).

Another explanation is base rate neglect. If intoxicated individuals lack the ability to accurately track events, they will overestimate the rate of target events when target events are rare and underestimate them when targets are frequent. From this perspective, the higher rate of positive responding by intoxicated individuals reflects a failure to correctly track the low rate of target events in vigilance paradigms (in which target events are, by tradition, relatively infrequent).

To evaluate whether base rate neglect plays a role in the results here, we must consider what an optimal policy is for criterion placement. Optimal criterion placement depends on knowledge of the base rate of events—in this case, of the occurrences of target stimuli (Green & Swets, 1966). Criterion placement should be more conservative in milieus when the target is infrequent, and should be more liberal when the target is frequent. In many experimental designs, the target rate is 50%, and the best strategy is to use an unbiased criterion. But, in designs in which the target rate is lower, the optimal criterion should be commensurately conservative (Tanner Jr & Swets, 1954).

Both concepts—disinhibition and base-rate neglect—predict that intoxicated individuals will exhibit greater deviation from an optimal criterion. We calculated the optimal criterion as $\sim$1.76 for the target rate of 0.18 (indicated as the red line in Figure 5) and compared the criterion placement with the optimal criterion. Subjects in the no-alcohol condition responded at rates that were closer to optimal bias and so appeared to be more tuned in to the target rate in the experiment. In addition, both groups exhibited some learning of the underlying event probabilities: criterion placement for both groups moved towards the optimal response bias over the course of the experiment.

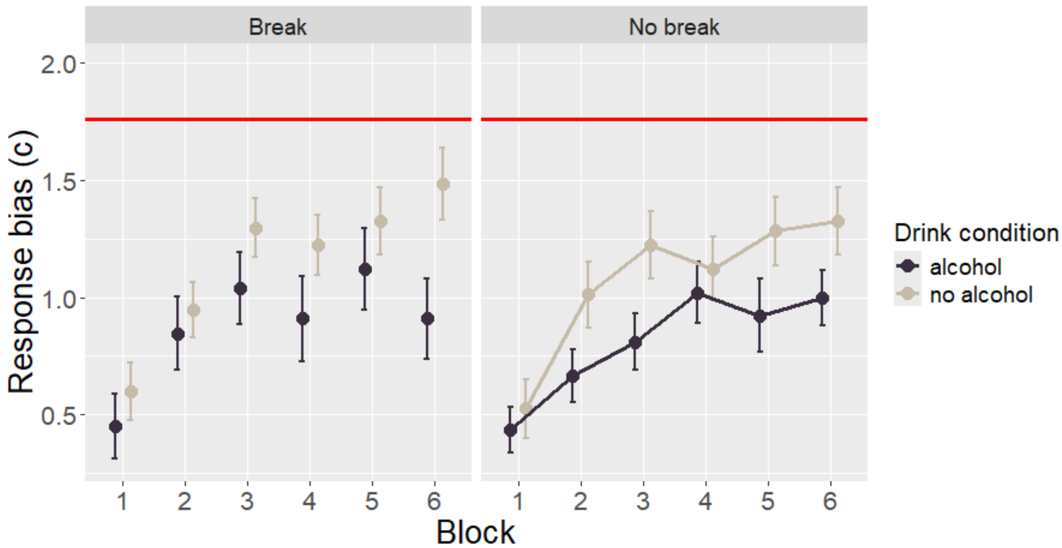
To examine whether base-rate neglect plays a unique role in this effect, we examined the magnitude of the deviation from an optimal criterion in the early vs. late stages of the experiment. The effect of disinhibition should result solely from the experimental condition and so should be roughly consistent across the experiment. However, base-rate neglect will be maximally apparent only after the subjects have had a genuine opportunity to learn the base rate of target events. In early blocks, both conditions have had limited chances to learn the target rate, so the consequence of neglecting that target base rate will be relatively minor. In later blocks, base-rate neglect will become more apparent and should manifest as a larger difference in criterion optimality between alcohol and no-alcohol groups.

We did an additional block-wise analyses of response bias but with more blocks and fewer trials per block so that we could better isolate the the potential effect of base rate neglect over time. A 2 (alcohol vs. no alcohol) by 2 (break vs. no break) by 6 (blocks) mixed ANOVA found a main effect of block ($F(5,1175) = 52.95$, $p < 0.001$, $\eta^2 = .046$) and an interaction between alcohol and blocks ($F(5,1175) = 2.60$, $p = .024$, $\eta^2 = 0.002$). In Figure 5, it can be seen that the response bias difference between drink conditions was barely apparent in early blocks but became more salient as the experiment progressed. That result indicates the contribution of base-rate neglect by intoxicated participants to the results. In early blocks, all participants responded in a very liberal manner, reflecting lack of knowledge of the low target rate. Over time, participants in the no-alcohol condition learned the base rate and adjusted their criteria more optimally.

A conservative shift in response bias has been reported in other perceptual tasks (e.g., Gyles et al., 2023; McCarley & Yamani, 2021), but base-rate neglect as a cause has not been broadly considered. In studies that manipulated target rate (e.g., Jansen et al., 1985; Wright & Mikkonen, 1970), we do see a more conservative criterion when the target rate is low, suggesting that participants are not fully unaware of the base rate. However, how criterion placement deviates from optimality and how it is affected by alcohol remain unclear. Here it appears that base-rate neglect plays a role in addition to the well-known

Figure 5

Block-by-block response bias comparison between break and alcohol conditions



Difference in response bias between drink conditions is more salient in later blocks. Error bars represent ± 1 between-subjects standard error.

effects of disinhibition. This discussion serves as a poignant reminder of why it is important to consider both hit and false-alarm rates when analyzing discrimination behavior.

Confirming prior research, breaks improved performance. Breaks as short as 30s led to significant performance improvement when we examine performance immediately before and after each break. This finding is in line with previous studies that investigated the effect of breaks on perceptual performance (e.g., Ariga & Lleras, 2011; Helton & Russell, 2015; Patel et al., 2024; Waldfogle et al., 2021). Longer breaks have been shown to provide even greater recovery (cf. Lim & Kwok, 2016), a point that may be of interest when designing future studies on the effect of alcohol on attention. In addition, on later blocks, when participants were more fatigued, the benefit of a break appears to be larger (cf. Yang & Benjamin, under review). One possible reason for not detecting a vigilance decrement is the lack of practice trials in our design. There was a large learning effect during the task, and the negative effects of vigilance decrement may be partly offset by the beneficial effects of task-set learning (Kumar et al., 2022) may be offset by a vigilance decrement in the no-break condition.

We also investigated whether the benefit of a break differed for sober and intoxicated subjects. Results from a whole-task analysis were equivocal, with Bayes Factors indicating neither support for nor a clear rejection of the hypothesis of an interaction between break presence and alcohol. Yet a localized analysis of performance revealed quite clearly that sober participants benefited more from the break than intoxicated subjects. This finding is novel and not anticipated by previous research that examined the interaction between alcohol and other factors that affect the state of subjects (e.g., Colquhoun & Edwards, 1975; Maylor & Rabbitt, 1987). The finding that both alcohol and no-alcohol groups benefited from the break, but that the benefit was more substantial for the control group suggests that sober individuals can use breaks as a means of preventing lapses of attention whereas intoxicated individuals may not be able to do so.

The causes of attention failure in vigilance tasks have long been debated. According to the mindlessness theory (Robertson et al., 1997; Smallwood & Schooler, 2013), simple repetitive tasks that pose minor cognitive load on individuals cause them to mind-wander more and thus be distracted from the ongoing task. Such phenomena are observed more often among intoxicated individuals (Sayette et al., 2009). Resource depletion theory (Kahneman, 1973) suggests that tasks that require continuous attention drain cognitive resources as time-on-task increases. There have been recent attempts to integrate the two theories. Thomson et al. (2015) proposed in their resource control account that executive control is the key to understanding the vigilance decrement. They argue that mind wandering is the default state. Executive control, as a function of motivation and task difficulty, allows individuals to direct attention to the ongoing task. Constant use of executive control consumes cognitive resources and makes sustaining attention harder when resources are depleted.

These theories propose two different (but not mutually exclusive) mechanisms for attention failures during sustained attention: mind wandering at low attentiveness (Smallwood et al., 2002, 2004) and inability to focus at high task difficulty or prolonged demands (Kane et al., 2007). The current study provides some hints as to the viability of each of these two mechanisms. Intoxicated individuals are known to be less attentive and mind wander more often (Sayette et al., 2009), a fact that can explain the overall depressed performance evident in the alcohol group. The differential effect of breaks between groups is also suggestive. Breaks provide an opportunity to recover resources but little incentive to cease mind-wandering and recover focus. Intoxicated participants may have continued in a state of disorganized attention, benefiting little from the break. Sober participants, on the other hand, recovered focus over the break and exhibited superior performance after the break. This fact suggests that resource depletion may have played a role, but that the specific effect of alcohol intoxication may be more directly on mind-wandering.

These findings may have some relevance for drunk-driving issues discussed previously, though caution is always warranted when attempting to generalize from results based on simple laboratory tasks to complex real-world behaviors. An individual who finds drunk-driving unacceptable while sober may still choose to drive while intoxicated because of disinhibition and alcohol myopia, leading them to focus on immediate goals (to get home quickly and conveniently) and ignore the danger. But, whereas a distracted individual who is sober will benefit from rest and recover their ability to bring necessary levels of attention to the complex task of driving (e.g., during a wait at a red light), the amount of recovery an intoxicated person can get from short breaks may not be as much as what people may expect. These findings suggest that the recovery from disinhibition or impaired attention during intoxication may be limited in comparison to sober individuals. However, further research is needed to fully understand how laboratory observations translate to real-world driving contexts. Efforts to promote responsible decision-making must consider not only the immediate effects of alcohol but also its longer-term consequences on individuals' ability to make sound judgments and prioritize safety.

Open Practices Statement

The datasets generated and analyzed during the current study are available in an OSF repository, https://osf.io/34ex5/ (Yang, 2024). Study materials are described in the Methods section. The data collected for this experiment were part of a larger study, which was preregistered at https://clinicaltrials.gov/study/NCT03449095?term=Fairbairn&rank=2.

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