

BRIEF REPORT

Effects of Alcohol on Sequential Information Processing: Evidence for Temporal Myopia

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Alcohol Myopia Theory (AMT) posits that alcohol restricts the focus of attention, such that behaviors are determined only by highly salient environmental cues. While AMT is most commonly understood in terms of spatial attention, the present study tested the effects of alcohol in the temporal domain of attention. Seventy-one participants consumed either a placebo beverage or one of two doses of alcohol (0.40g/kg or 0.80g/kg ETOH) before performing an auditory discrimination task while event-related potentials (ERPs) were recorded. Consistent with typical sequential effects, placebo participants showed increased P300 amplitude and slowed behavioral responses when the current target differed from the two-back tone. In contrast, alcohol caused increased P300 and response slowing when the target tone differed from the one-back tone. These findings suggest that alcohol increases the salience of more recently encountered information, consistent with the general tenets of AMT.

Keywords: alcohol, attention, sequential effects, P300, event-related potentials

Alcohol use is widely known to produce numerous social and behavioral problems, including aggression (Critchlow, 1986; Giancola, 2000), risky sex (e.g., Cooper, 1992; Testa & Collins, 1997), and personal injury (Perkins, 1992). Most contemporary theories posit that these outcomes reflect the drug's impairment of various cognitive processes, ostensibly leading to incomplete stimulus evaluation and short-sighted decision making (e.g., Graham, 1980; Sayette, 1999; Steele & Josephs, 1988). In particular, the prominent Alcohol Myopia Theory (AMT; Steele & Josephs, 1990) posits that alcohol reduces the scope and focus of attention, limiting both the range of cues that can be perceived and the ability to process those cues that are perceived. Consequently, behavioral responses are thought to be based on only the most immediate, salient environmental cues, at the expense of processing and responding to more peripheral cues. Findings con-

sistent with AMT have a number of real-world implications. For example, attending to a potential partner's physical attractiveness at the expense of more peripheral information (e.g., knowing nothing about his or her sexual history) could lead to greater sexual risk taking. Likewise, the salience of one's own craving and/or social-environmental cues to continue drinking could lead someone to drink more than intended, with potentially dangerous consequences in numerous domains.

AMT is most often understood in terms of the spatial domain of attention, and typically has been tested in the context of tasks that require participants to divide attention across multiple spatial domains (e.g., do Canto-Pereira, David, Machado-Pinheiro, & Ranvaud, 2007; Curtin, Patrick, Lang, Cacioppo, & Birbaumer, 2001; Fisk & Scerbo, 1987; Giancola & Corman, 2007). Although many such studies have reported support for AMT, careful consideration of task demands in such paradigms suggests that they may be tapping task-switching ability (i.e., rapidly switching attention between mental sets and operations; Monsell, 1996), often considered a component of higher-order executive control processes (Miyake et al., 2000), in addition to or instead of the span of visual attention. Alcohol is believed to particularly impair executive functioning (e.g., Casbon, Curtin, Lang, & Patrick, 2003; Peterson, Rothfleisch, Zelazo, & Pihl, 1990), and thus alcohol might impair performance in tasks involving switching for that reason rather than because attention span is reduced.

Studies using tasks that isolate alcohol effects on spatial attention often have failed to obtain results consistent with AMT (e.g., Post, Chaderjian, & Maddock, 2000; Sauls, Cowan, Sher, & Moreno, 2007). For example, Sauls et al. (2007) isolated the effects of alcohol on the storage capacity of working memory,

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associated with attention span (Cowan et al., 2005), from other processes involved in memory performance. Participants judged whether a comparison stimulus set (sequences or arrays of items) differed from an initial set. Alcohol had no effect on the number of array items held in the focus of attention, but rather impaired memory for stimulus sequences, suggesting that alcohol's effects are more pronounced in the temporal than in the spatial domain.

Effects of varying sequences of events in working memory have been studied extensively using event-related brain potentials (ERPs). Decades of research have shown that variations in the amplitude of the P300 (or P3b; for reviews see Donchin, 1981; Fabiani, Gratton, & Federmeier, 2007) component of the ERP reflect the extent to which representation of a target stimulus is active in working memory (e.g., Brumback, Low, Gratton, & Fabiani, 2005; Peltz, Gratton, & Fabiani, 2011; Gonsalvez & Polich, 2002; Leuthold & Sommer, 1993; Squires, Petuchowski, Wickens, & Donchin, 1977; Squires, Wickens, Squires, & Donchin, 1976). Specifically, stimuli representing a category that differs from more distal events elicit larger P3b amplitude than stimuli differing from more proximal events. In the first known demonstration of this phenomenon, Squires et al. (1976) recorded ERPs while participants performed a tone classification task and found larger P3b amplitudes to targets differing from the tone presented two trials previously (i.e., two-back tone) compared to targets differing from the tone presented on the immediately preceding trial (i.e., one-back tone). Such "sequential effects" suggest that mental representations of more distal events are fainter than more proximal events, which are still actively represented and thus do not require updating (Donchin & Coles, 1988).

To the extent that alcohol restricts the focus of temporal attention, events occurring more recently should have a larger effect on processing (i.e., necessitate more updating of working memory contents) than events occurring less recently. If so, the classic "sequential effect" pattern of P3b amplitude (e.g., Squires et al., 1976) could be altered or reversed following alcohol relative to placebo consumption. Specifically, following the tenets of AMT, unusual weight could be assigned to the most recently encountered information, such that stimuli differing from that recently encountered information elicit an uncharacteristically large P3b response. This study sought to test that hypothesis.

Method

Participants

Seventy-one current drinkers (38 men), ages 21–29 ($M = 22$), were recruited from Urbana-Champaign, IL, through newspaper advertisements and flyers announcing a study on alcohol and cognition. Potential participants were called to determine their eligibility via a structured telephone interview. Individuals were deemed ineligible if they indicated any major medical concerns that contraindicate alcohol administration (e.g., pregnancy or breast-feeding; history of serious mental or physical illness; symptoms of alcohol or drug dependence; prescription medication other than contraception), reported history of head trauma or neurological disorder, reported drinking on average less than two or more than 25 drinks per week in the past 3 months, or reported not having experienced a binge drinking episode (five or more drinks on one occasion) in the past 6 months (to ensure that the alcohol

dose received in the study would be within participants' typical range of experience; see Chan, Neighbors, Gilson, Larimer, & Marlatt, 2007). Eligible individuals agreed to adhere to a pre-experimental protocol involving abstinence from alcohol and drugs for 24 hours, abstinence from exercise for 3 hours, and eating a meal 4–6 hours prior to their session. Compliance was assured via signed affidavits. Participants were paid \$8/hour.

Stimuli and Experimental Paradigm

Participants completed an auditory discrimination task in which two tones (350 Hz and 500 Hz) were presented randomly in a series with equal probability. The tones (duration 350 ms, 10 ms rise and fall times, 80 dB in loudness) were presented through earphones and controlled via a sound card, at the rate of one every 1.6 seconds. Participants were asked to categorize every tone as either high or low as quickly and accurately as possible by pressing a button with the left or right index finger (counterbalanced across participants). Five blocks of 100 trials each were completed. Brief breaks of approximately 2 min were inserted between blocks.

Electrophysiological Recording and Analysis

The electroencephalogram (EEG) was recorded from 32 tin electrodes embedded in electrode caps (NeuroMedical Supplies, Inc., Charlotte, NC) and placed according to an expanded 10–20 system. The left mastoid served as the online reference; an average mastoid reference was computed offline. Vertical and horizontal eye movements were measured using additional bipolar electrodes placed just above and below the left eye and approximately 2 cm from the outer canthus of each eye, respectively. Eye movement artifacts were removed from the EEG signal offline (Gratton, Coles, & Donchin, 1983). The data were bandpass-filtered (0.01–30 Hz) online and digitized at 100 Hz for 1000 ms, with a 100-ms baseline. Impedance was kept below 10 k Ω at all locations. Amplifier gain was set at 10,000. Trials exceeding the A/D converter range and those with peaks exceeding 300 microvolts (μ V) were excluded from the data prior to averaging according to participant, stimulus, and electrode conditions. P3b amplitude was scored as the average voltage 200–450 ms poststimulus.

Procedure

Upon arrival at the lab, participants provided informed consent, completed a number of questionnaire measures (some of which assessed their typical alcohol use; see Table 1), and were randomly assigned to one of three beverage groups: high alcohol dose (0.80g/kg ethanol for men, 0.72g/kg for women), low alcohol dose (0.40g/kg ethanol for men, 0.36g/kg for women), or placebo (0.04g/kg ethanol).¹ A breathalyzer (Alco-Sensor IV; Intoximeters, St. Louis, MO) was used to sample breath alcohol concentration (BrAC) to ensure initial sobriety. Women self-administered a urine-stream pregnancy test (all were negative) in a private restroom; men were also asked to use the restroom. Participants were then seated in a soundproof recording chamber for electrode

¹ A more detailed description of beverage administration procedures is provided in previous reports (Bartholow et al., 2003; Bartholow et al., 2006).

Table 1
Typical Alcohol Use for Participants in Each Beverage Condition

	Placebo		Low dose		High dose	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Alc. quantity	4.64	1.86	4.21	1.41	5.22	2.07
Alc. frequency	1.47	0.93	1.77	1.10	1.93	1.45
Heavy drinking	0.93	0.82	0.96	0.93	1.26	0.71

Note. Alc quantity = number of drinks consumed in a typical drinking episode in the past year; Alc. frequency = typical number of drinking episodes per week in the past year; Heavy drinking = average of the number of times high from alcohol, number of times drunk, and number of binge-drinking episodes in the past 30 days. A series of one-way ANOVAs comparing means of these variables across beverage groups showed no significant group differences ($F_s < 1$). The somewhat higher means evident in the high-dose group compared to the other groups reflects the influence of a single individual whose drinking patterns were atypically heavy.

placement and testing. After electrophysiological recording and task procedures were explained, participants completed a short practice block to familiarize them with the task prior to beverage consumption.

All participants were told they had been assigned to consume a "moderate amount of alcohol." Each session involved two experimenters, one of whom was unaware of beverage condition assignment and was charged with mixing and serving the beverages in three equal-sized drinks (the other experimenter took all BrAC measurements). Participants were given 15 min to consume their drinks, after which they sat idly for 20 min to allow the alcohol to absorb.

Following a BrAC measurement, participants completed the experimental trials (BrAC was also measured between all blocks), after which they completed a brief postexperimental questionnaire to assess subjective intoxication and perceptions of the experiment prior to being debriefed. Alcohol group participants were retained in the lab until their BrAC was $\leq 0.02\%$, at which time they were driven home by a friend or in a taxi provided by the experimenters.

Results

Analytic Approach

Due to excessive artifact, EEG data from 10 participants (two high-dose, four low-dose, and four placebo) had to be excluded

from analyses of the P3b; behavioral data from these participants was included in analyses, however. Also, behavioral data from one participant (placebo) were not recorded, but this participant's EEG data were used in P3b analyses. To control for alpha inflation, Tukey's HSD contrasts were used for mean comparisons following significant interactions. Initial analyses including participant sex as a factor showed that none of the predicted effects were moderated by sex. Thus, for simplicity, we report analyses collapsing across sex.

Our main interest was in the effects of the beverage manipulation on processing targets that differed from stimuli encountered more distally versus more recently. To that end, we constructed means for four types of stimulus sequences for each dependent variable, representing whether a current target (X) was the same as or differed from stimuli encountered one-back and two-back, that is, XXX , YXX , XYX , and YYX , resulting in a three (Group; placebo, low dose, high dose) \times two (N -back; one-back, two-back) \times two (Trial type; no change, change) mixed factorial ANOVA design, with repeated measures on the latter factors. The primary prediction for each analysis was that alcohol would increase the relative influence of change from recent compared to more distal events on target processing (i.e., slower reaction time [RT] and larger P3b on one-back change relative to one-back no-change trials), which would manifest as a significant Group \times N -back \times Trial Type interaction. Significant interactions were

Table 2
Mean Response Times and Accuracy Rates as a Function of Stimulus Conditions and Beverage Groups

Group	Current targets' relationship with previous targets			
	One-back		Two-back	
	No change	Change	No change	Change
Placebo ($n = 23$)	361.4 (84.4) .95 (.06)	357.5 (82.5) .93 (.07)	348.7 (85.8) .95 (.05)	370.2 (79.7) .93 (.05)
Low dose ($n = 24$)	334.4 (84.3) .95 (.06)	350.8 (82.4) .92 (.07)	335.2 (85.7) .95 (.05)	350.0 (79.5) .92 (.08)
High dose ($n = 22$)	365.7 (84.8) .94 (.06)	371.0 (82.8) .92 (.07)	360.1 (86.2) .95 (.05)	376.6 (79.9) .91 (.08)

Note. Numbers in parentheses are standard deviations. The top row in each cell is the reaction time in ms; the bottom row in each cell is the proportion of correct responses.

probed by creating difference scores representing the one-back and two-back effects (e.g., difference in RT for change relative to no-change trials) as a function of beverage group, and comparing the magnitude of these scores both between and within groups.

Manipulation Check

Baseline BrAC for all participants was zero, and remained that way for placebo participants throughout the study. Postdrinking BrAC levels for the alcohol groups before, during, and after the auditory discrimination task were analyzed using a two (Dose) \times two (Sex) \times three (Assessment time) analysis of variance (ANOVA) with repeated measures on the last factor. BrACs were higher in the high-dose group ($M = 0.079\%$, $SD = 0.02$) than in the low-dose group ($M = 0.039\%$, $SD = 0.01$), $F(1, 45) = 39.80$, $p < .01$. No other effects were significant in this analysis (all F s < 1.4 , $ps > .26$). Linear contrasts showed that BrAC did not change reliably from pretask to posttask in either the low-dose group (M s = .042, .039, and .037), $F(1, 45) = 2.69$, $p = .11$, or the high-dose group (M s = .079, .079, .080), $F < 1$. Postexperiment estimates of the number of standard drinks participants believed they consumed differed by group (M s = 2.45, 3.38 and 4.12 for placebo, low-dose and high-dose, respectively), $F(2, 68) = 9.07$, $p < .01$. Post hoc Tukey contrasts indicated that only the high-dose and placebo group estimates differed significantly ($p < .001$). The fact that placebo participants believed, on average, that they had consumed nearly 2.5 drinks attests to the validity of our placebo manipulation, $t(20) = 11.46$, $p < .001$.

Task Performance

Reaction time (RT). Behavioral performance data are given in Table 1. The ANOVA on the average RTs showed a significant N -back \times Trial type interaction, $F(1, 66) = 12.80$, $p < .01$, $\eta_p^2 = 0.16$, as well as a Group \times N -back \times Trial type interaction, $F(2, 66) = 5.86$, $p < .01$, $\eta_p^2 = 0.17$.² Figure 1 displays the essence of this interaction using difference scores, as described previously. Separate one-way ANOVAs indicated that whereas the one-back

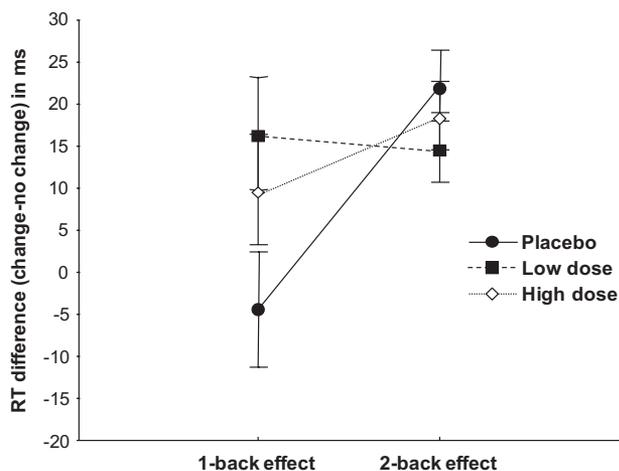


Figure 1. One-back and two-back effects on RT (difference in RT for change versus no-change sequences) as a function of beverage group. Vertical bars indicate ± 1 SE.

effect differed marginally across beverage groups, $F(2, 66) = 2.79$, $p < .07$, no such difference was apparent for the two-back effect ($F < 1$). Follow-up Tukey's HSD contrasts showed that the one-back effect was larger in both alcohol groups than in the placebo group ($ps < .05$) and that the effect was similar in both alcohol groups ($p > .40$). Stated another way, whereas the one-back effect did not reliably differ from zero for placebo participants, $t(21) = -0.64$, $p = .52$, indicating no effect of the immediately preceding tone on the response to the current tone, a change from the one-back tone significantly slowed RTs for those who consumed alcohol, $t(46) = 2.48$, $p < .015$.

Accuracy. To normalize the distribution for ANOVA, accuracy rates were transformed by calculating the arcsine of the square root of the proportion correct. The ANOVA on these transformed data showed a main effect of Trial type, $F(1, 66) = 154.7$, $p < .001$, indicating that responses were more accurate on no-change than on change trials. No other effects were significant.

P3b Amplitude

Initial analyses of P3b amplitude across midline electrode locations (Fz, Cz, Pz) indicated that the P3b was largest at electrode Pz (parietal), $F(2, 114) = 46.38$, $p < .01$. Thus, our primary analysis focused on data from Pz.³ ERP waveforms recorded at Pz are presented in Figure 2. Similar to the RT data, analysis of P3b amplitude showed a significant Group \times N -back \times Trial type interaction $F(2, 57) = 4.30$, $p < .02$, $\eta_p^2 = 0.13$ (see Figure 3).⁴ Although separate one-way ANOVAs testing for beverage group differences in the size of the one-back and two-back effects (i.e., change–no change difference scores) showed no significant group effects (F s < 1.9 , $ps > .16$), Tukey's HSD contrasts indicated that the magnitude of the difference between the one-back and two-back effects varied across beverage groups. Specifically, whereas the two-back effect was larger than the one-back effect for placebo participants ($p = .018$), the one-back and two-back effects did not differ significantly for those in the alcohol groups ($ps > .50$).

Discussion

Consistent with predictions derived from the AMT and from previous research (Saults et al., 2007), the current results indicate

² Given the possibility that individual differences in typical alcohol use could result in differential effects of acute intoxication (i.e., differences in sensitivity or tolerance), we conducted an ancillary analysis in which past-year quantity/frequency of alcohol use was included as a covariate. This analysis produced a Group \times N -back \times Trial type interaction similar to the one reported in the text: $F(2, 63) = 3.17$, $p < .05$, and the quantity/frequency variable did not interact with any other terms in the model (all F s < 1).

³ Ancillary analyses in which the predicted interaction was tested using data from other electrode locations showed that the Group \times N -back \times Trial type interaction also emerged at electrode Cz, $F(2, 57) = 5.05$, $p < .01$, as well as at electrode Fz, $F(2, 57) = 3.84$, $p < 0.03$.

⁴ As with the RT data, we conducted an ancillary analysis of the P3 amplitude data in which past-year quantity/frequency was included as a covariate. This analysis produced a Group \times N -back \times Trial type interaction similar to the one reported in the text: $F(2, 55) = 4.05$, $p < .05$, and the quantity/frequency variable did not interact with any other terms in the model (all F s < 1).

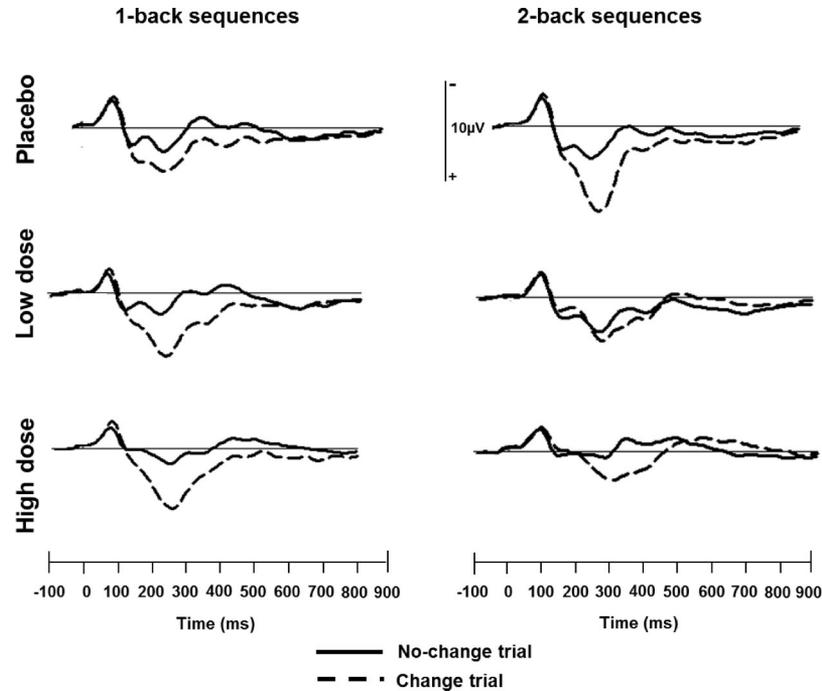


Figure 2. ERP waveforms measured at the Pz electrode elicited by current tones as a function of whether they represent a change or no change from the tones occurring one-back and two-back for participants in the three beverage groups.

that alcohol consumption enhances the influence of recently encountered information relative to more distal information. Targets representing a change from an immediately preceding event typically have less effect on processing than do changes from more distal events (e.g., Brumback et al., 2011; Leuthold & Sommer, 1993; Squires et al., 1977), a pattern replicated here in the placebo group. However, target processing among those who consumed alcohol was considerably affected by differences with the more

recently preceding stimulus, evidenced by slower RTs and unusually large P3b responses to targets differing from the one-back tone. Given evidence that auditory sensory memory processes are obligatory, occurring regardless of intentions to attend or update memory contents (see Cowan, 1984), the current findings arguably present clearer support for the attention-narrowing hypothesis underlying AMT than have previous studies involving tasks that rely on higher-order cognitive control processes (e.g., Post et al., 2000; Rohrbaugh et al., 1988).

In light of current understanding of sequential effects in P3b amplitude (see Donchin & Coles, 1988), two possible explanations for the current results should be considered. First, it could be that alcohol impairs working memory performance so severely that representations of recently encountered items deteriorate very rapidly, such that even a change from the one-back tone triggers updating. This explanation seems unlikely, however, for three reasons. First, the doses of alcohol administered here were relatively small; given other data on cognitive effects of alcohol at comparable doses (e.g., Bartholow et al., 2003; Giancola & Corman, 2007; Pihl, Paylan, Genten-Hawn, & Hoaken, 2003; Sauls et al., 2007), it would be surprising if this level of intoxication produced such a drastic impairment in working memory. Second, participants in all beverage groups responded more slowly to targets differing from the one presented two-back. Thus, a memory trace for the two-back stimulus must remain intact following alcohol ingestion, and thus so must the representation of the one-back tone. Rather, the alcohol groups differed in terms of the relative significance given to the match or mismatch of the current stimulus with the one immediately preceding it, implicating an

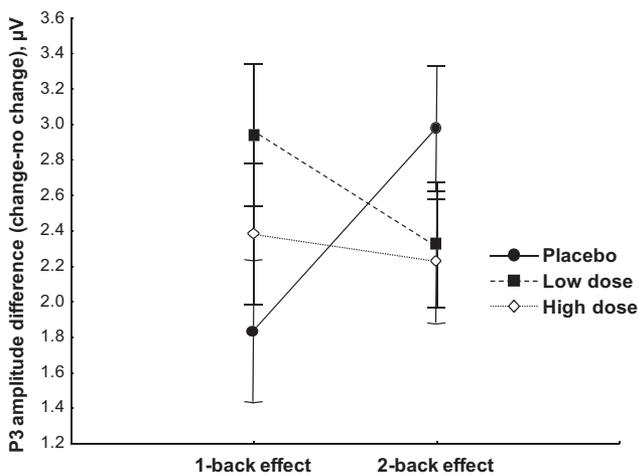


Figure 3. One-back and two-back effects in P3b amplitude (difference in P3 for change versus no-change sequences) as a function of beverage group. Vertical bars indicate ± 1 SE.

attentional rather than a memory phenomenon as responsible for the observed effects. Finally, other recent studies suggest that problems with working memory produce a different pattern from the one observed here. Brumback and colleagues (Brumback et al., 2005; Peltz et al., 2011) have shown that, relative to their peers higher in working memory capacity, individuals with relatively low working memory capacity tend to experience larger P3b amplitude for targets differing from two-back tones (i.e., an enhancement of the typical sequential effect). This finding is thought to reflect greater difficulty among low-span individuals in keeping track of stimulus sequences, prompting an enhanced need to update memory representations.

The second and seemingly more likely explanation of the current findings is that they reflect a kind of "temporal myopia," in which alcohol leads to an unusual focus on the most recently encountered information. Changes from such recent information appear to prompt updating efforts, as indicated by both slowed behavioral responses and enhanced P3b amplitudes to targets differing from one-back tones following alcohol ingestion. In contrast, changes from more proximal events had little effect on brain and behavioral responses among participants in the placebo group. Taken together, these findings provide support for the view that alcohol influences the temporal scope or span of attention by enhancing the focus of attention on the most salient (i.e., recent) environmental cues, and extend other findings (e.g., Post et al., 2000; Rohrbaugh et al., 1988) by demonstrating an alcohol effect in a task that does not rely on higher-order attention control processes.

The current findings could have implications for understanding intoxicated risky decision making. To the extent that behavioral decisions (e.g., to engage in sex with a new partner, to continue a drinking episode, to pick a fight) typically represent the outcome of a relative weighting of both currently salient information and more distal, potentially inhibitory cues, the current findings suggest that alcohol could bias decisions through unusual weight being assigned to more recently encountered information, potentially resulting in riskier choices.

This study suffered from some notable limitations. First, the study design was limited by the lack of a pure control beverage group and, therefore, the potential for alcohol expectancy effects to influence placebo group responses could not be assessed. However, given the similarities in behavioral and P3b responses observed in the current placebo group and in previous studies not involving a beverage manipulation (e.g., Brumback et al., 2005; Squires et al., 1976, 1977), it seems unlikely that such an explanation could account for the beverage effects observed here. Also, the fact that postexperiment estimates of the number of drinks consumed differed across beverage groups suggests that subjective effects could have played some role in the group differences we report. Second, although comparable in size to previous alcohol challenge studies (e.g., Casbon et al., 2003; Curtin et al., 2001; Sauls et al., 2007), the current sample size was modest. Future work should involve larger samples to permit examination of potentially interesting individual differences, such as working memory span or familial alcoholism risk. Finally, although the simplicity of the task and stimuli represent strengths of the current study in terms interpreting effects on attention per se as distinct from higher-order attention control, this feature also could make

extrapolation of the current results to other content domains difficult.

In conclusion, the current findings provide evidence that moderate doses of alcohol enhance focus on recently encountered information, suggesting the presence of alcohol myopia in the temporal domain. The use of a very simple task, relying on the relatively obligatory nature of auditory sensory processing (see Cowan, 1984) and requiring minimal effortful engagement, allowed us to dissociate effects on attention from those pertaining to memory per se, thereby providing novel data on the attention-restricting properties of alcohol. In this way, the current study provides some of the first evidence that alcohol's attention-narrowing effects occur even in the absence of demanding task requirements. Given the general thesis that alcohol largely affects control-related processes while leaving more automatic processes unaffected (e.g., Bartholow, Dickter, & Sestir, 2006; Fillmore & Vogel-Sprott, 1999; Fillmore, Vogel-Sprott, & Gavrilesco, 1999), future research should investigate the extent to which the current findings might extend to or influence understanding of alcohol effects on other cognitive operations often posited to be obligatory or automatic.

References

- Bartholow, B. D., Dickter, C. L., & Sestir, M. A. (2006). Stereotype activation and control of race bias: Cognitive control of inhibition and its impairment by alcohol. *Journal of Personality and Social Psychology, 90*, 272–287. doi:10.1037/0022-3514.90.2.272
- Bartholow, B. D., Pearson, M. A., Sher, K. J., Wieman, L. C., Fabiani, M., & Gratton, G. (2003). Effects of alcohol consumption and alcohol susceptibility on cognition: A psychophysiological examination. *Biological Psychology, 64*, 167–190. doi:10.1016/S0301-0511(03)00108-X
- Brumback, C. R., Low, K. A., Gratton, G., & Fabiani, M. (2005). Putting things into perspective: Individual differences in working-memory span and the integration of information. *Experimental Psychology, 52*, 21–30. doi:10.1027/1618-3169.52.1.21
- Casbon, T. S., Curtin, J. J., Lang, A. R., & Patrick, C. J. (2003). Deleterious effects of alcohol intoxication: Diminished cognitive control and its behavioral consequences. *Journal of Abnormal Psychology, 112*, 476–487. doi:10.1037/0021-843X.112.3.476
- Chan, K. K., Neighbors, C., Gilson, M., Larimer, M. E., & Marlatt, G. A. (2007). Epidemiological trends in drinking by age and gender: Providing normative feedback to adults. *Addictive Behaviors, 32*, 967–976. doi:10.1016/j.addbeh.2006.07.003
- Cooper, M. L. (1992). Alcohol and increased behavioral risk for AIDS. *Alcohol Health & Research World, 16*, 64–72.
- Cowan, N. (1984). On short and long auditory stores. *Psychological Bulletin, 96*, 341–370. doi:10.1037/0033-2909.96.2.341
- Cowan, N., Elliot, E. M., Sauls, J. S., Morey, C., Mattox, S., Hismatjulina, A., & Conway, A. R. A. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology, 51*, 42–100. doi:10.1016/j.cogpsych.2004.12.001
- Critchlow, B. (1986). The powers of John Barleycorn: Beliefs about the effects of alcohol on social behavior. *American Psychologist, 41*, 751–764. doi:10.1037/0003-066X.41.7.751
- Curtin, J. J., Patrick, C. R., Lang, A. C., Cacioppo, J. T., & Birbaumer, N. (2001). Alcohol affects emotion through cognition. *Psychological Science, 12*, 527–531. doi:10.1111/1467-9280.00397
- do Canto-Pereira, L. H., David, I. P. A., Machado-Pinheiro, W., & Ranaivosoa, R. D. (2007). Effects of acute alcohol intoxication on visuospatial attention. *Human and Experimental Toxicology, 26*, 311–319. doi:10.1177/0960327106070490

- Donchin, E. (1981). Surprise! . . . Surprise? *Psychophysiology*, *18*, 493–513. doi:10.1111/j.1469-8986.1981.tb01815.x
- Donchin, E., & Coles, M. G. (1988a). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, *11*, 357–427. doi:10.1017/S0140525X00058027
- Fabiani, M., Gratton, G., & Federmeier, K. (2007). Event related brain potentials. In J. Cacioppo, L. Tassinary, & G. Berntson (Eds.), *Handbook of psychophysiology* (3rd ed, pp. 85–119). New York, NY: Cambridge University Press.
- Fillmore, M. T., & Vogel-Sprott, M. (1999). An alcohol model of impaired inhibitory control and its treatment in humans. *Experimental and Clinical Psychopharmacology*, *7*, 49–55. doi:10.1037/1064-1297.7.1.49
- Fillmore, M. T., Vogel-Sprott, M., & Gavrilescu, D. (1999). Alcohol effects on intentional behavior: Dissociating controlled and automatic influences. *Experimental and Clinical Psychopharmacology*, *7*, 372–378. doi:10.1037/1064-1297.7.4.372
- Fisk, A. D., & Scerbo, M. W. (1987). Automatic and control processing approach to interpreting vigilance performance: A review and reevaluation. *Human Factors*, *29*, 653–660.
- Giancola, P. R. (2000). Executive functioning: A conceptual framework for alcohol-related aggression. *Experimental and Clinical Psychopharmacology*, *8*, 576–597. doi:10.1037/1064-1297.8.4.576
- Giancola, P. R., & Corman, M. D. (2007). Alcohol and aggression: A test of the attention-allocation model. *Psychological Science*, *18*, 649–655. doi:10.1111/j.1467-9280.2007.01953.x
- Gonsalvez, C. J., & Polich, J. (2002). P300 amplitude is determined by target-to-target interval. *Psychophysiology*, *39*, 388–396. doi:10.1017/S0048577201393137
- Graham, K. (1980). Theories of intoxicated aggression. *Canadian Journal of Behavioural Science*, *12*, 141–158. doi:10.1037/h0081045
- Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography & Clinical Neurophysiology*, *55*, 468–484. doi:10.1016/0013-4694(83)90135-9
- Leuthold, H., & Sommer, W. (1993). Stimulus presentation rate dissociates sequential effects in event-related potentials and reaction times. *Psychophysiology*, *30*, 510–517. doi:10.1111/j.1469-8986.1993.tb02074.x
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzke, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. doi:10.1006/cogp.1999.0734
- Monzell, S. (1996). Control of mental processes. In V. Bruce (Ed.), *Unsolved mysteries of the mind: Tutorial essays in cognition* (pp. 93–148). Oxford, UK: Taylor & Francis.
- Peltz, C. B., Gratton, G., & Fabiani, M. (2011). Age-related changes in electrophysiological and neuropsychological indices of working memory, attention control, and cognitive flexibility. *Frontiers in Psychology*, *2*, 1–12. doi:10.3389/fpsyg.2011.00190
- Perkins, H. W. (1992). Gender patterns in consequences of collegiate alcohol abuse: A 10-yr study of trends in an undergraduate population. *Journal of Studies on Alcohol*, *53*, 458–462.
- Peterson, J. B., Rothfleisch, J. M., Zelazo, P. D., & Pihl, R. O. (1990). Acute alcohol intoxication and cognitive functioning. *Journal of Studies on Alcohol*, *51*, 114–122.
- Pihl, R. O., Paylan, S. S., Genten-Hawn, A., & Hoaken, P. N. S. (2003). Alcohol affects executive cognitive functioning differentially on the ascending versus descending limb of the blood alcohol concentration curve. *Alcoholism: Clinical and Experimental Research*, *23*, 773–779. doi:10.1145-6008/03/2705-0773\$03.00/0
- Post, R. B., Chaderjian, M. R., & Maddock, R. J. (2000). Effects of alcohol on exogenous precueing of attention. *Journal of Studies on Alcohol*, *61*, 232–238.
- Rohrbaugh, J. W., Stapleton, J. M., Parasuraman, R., Frowein, H., Adinoff, B., Varner, J. L., . . . Linnoila, M. (1988). Alcohol intoxication reduces visual sustained attention. *Psychopharmacology*, *96*, 442–446. doi:10.1007/BF02180021
- Saults, J. S., Cowan, N., Sher, K. J., & Moreno, M. (2007). Differential effects of alcohol on working memory: Distinguishing multiple processes. *Experimental and Clinical Psychopharmacology*, *15*, 576–587. doi:10.1037/1064-1297.15.6.576
- Sayette, M. A. (1999). Cognitive theory and research. In K. Leonard, & H. Blane (Eds.), *Psychological theories of drinking and alcoholism* (2nd ed., pp. 247–291). New York, NY: Guilford Press.
- Squires, K. C., Petuchowski, S., Wickens, C., & Donchin, E. (1977). The effects of stimulus sequence on event related potentials: A comparison of visual and auditory sequences. *Attention, Perception, & Psychophysics*, *22*, 31–40. doi:10.3758/BF03206077
- Squires, K. C., Wickens, C., Squires, N. K., & Donchin, E. (1976). The effect of stimulus sequence on the waveform of the cortical event-related potential. *Science*, *193*, 1142–1146. doi:10.1126/science.959831
- Steele, C. M., & Josephs, R. A. (1988). Drinking your troubles away: II. An attention-allocation model of alcohol's effect on psychological stress. *Journal of Abnormal Psychology*, *97*, 196–205. doi:10.1037/0021-843X.97.2.196
- Steele, C. M., & Josephs, R. A. (1990). Alcohol myopia: Its prized and dangerous effects. *American Psychologist*, *45*, 921–933. doi:10.1037/0003-066X.45.8.921
- Testa, M., & Collins, R. L. (1997). Alcohol and risky sexual behavior: Event-based analyses among a sample of high-risk women. *Psychology of Addictive Behaviors*, *11*, 190–201. doi:10.1037/0893-164X.11.3.190

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