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BRIEF REPORTS

Electrophysiological Evidence of Alcohol-Related Attentional Bias in Social Drinkers Low in Alcohol Sensitivity

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Low sensitivity to the acute effects of alcohol is a known risk factor for alcoholism. However, little is known concerning potential information-processing routes by which this risk factor might contribute to increased drinking. We tested the hypothesis that low-sensitivity (LS) participants would show biased attention to alcohol cues, compared with their high-sensitivity (HS) counterparts. Participants performed a task in which alcoholic and nonalcoholic beverage cues were presented bilaterally followed by a target that required categorization by color. Response times were faster for targets appearing in alcohol-cued than non–alcohol-cued locations for LS but not for HS participants. Event-related potential markers of early attention orienting (P1 amplitude) and subsequent attention reorienting (ipsilateral invalid negativity amplitude) indicated preferential selective attention to alcohol-cued locations among LS individuals. Controlling for recent drinking and family history of alcoholism did not affect these patterns, except that among HS participants, relatively heavy recent drinking was associated with difficulty reorienting attention away from alcohol-cued locations. These findings suggest a potential information-processing bias through which low sensitivity could lead to heavy alcohol involvement.

Keywords: alcohol cues, event-related brain potentials, IIN, ERP, attention, capture, Neural, brain

Theories of addiction focusing on cognitive–motivational processes hypothesize that substance abuse often is accompanied by enhancement in the motivational salience of drug-related stimuli, such that encountering drug cues activates appetitive/approach motivational states that enhance the likelihood of use (e.g., Carter & Tiffany, 1999; Franken, 2003; Robinson & Berridge, 2001, 2003; Stewart, DeWitt, & Eikelboom, 1984). The tight coupling of motivation and attention (e.g., Engelmann & Pessoa, 2007; Lang, 1995) suggests that users also should preferentially attend to substance-related cues, a hypothesis supported by numerous studies in the alcohol literature showing, for example, that heavy compared with moderate social drinkers (e.g., Cox, Yeates, & Regan, 1999; Duka & Townshend, 2004; Townshend & Duka, 2001) and alcohol-dependent compared with nondependent drinkers (e.g., Cox, Hogan, Kristina, & Race, 2002; Fadardi & Cox, 2006; Lusher, Chandler, & Ball, 2004; Ryan, 2002; Sharma, Albery, & Cook, 2001) show a bias in attending to alcohol-related (relative to non–alcohol-related) cues. Such biases are troubling because heightened attention to alcohol cues is known to increase alcohol-related risk processes, such as motivation to drink (e.g., Field & Eastwood, 2005).

In general, such biases in motivation and attention are theorized to develop over time as a function of increasing alcohol use (see Carter & Tiffany, 1999; Robinson & Berridge, 2001, 2003; Stritzke, Breiner, Curtin, & Lang, 2004). However, recent research in our laboratory suggests that a specific risk factor for alcohol abuse—namely, low sensitivity to alcohol's acute effects (see Schuckit, 1994; Schuckit & Smith, 2000)—can predict enhanced reactivity to alcohol-related cues beyond what can be attributed to previous alcohol involvement. In two previous experiments (Bartholow, Henry, & Lust, 2007; Bartholow, Lust, & Tragesser, in press), low-sensitivity (LS) individuals (relative to high-sensitivity [HS] individuals) showed enhanced reactivity to alcohol cues in the P3 component of the event-related brain potential (ERP), reflecting enhanced activation of the appetitive motivational system (e.g., Carretié, Mercado, & Tapia, 2000; Ito, Larsen, Smith, & Cacioppo, 1998; Schupp et al., 2000). It is important to note that, although LS individuals often drink more than their HS counter-

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parts, these findings have emerged even after controlling for differences in alcohol use and other risk factors such as family history of alcoholism and impulsivity.

Previously, we have argued that enhanced P3 reactivity to alcohol cues might represent an endophenotype (i.e., state-independent, intermediate phenotype linking underlying genetic vulnerability with clinical outcomes; see Cannon & Keller, 2006; Gottesman & Gould, 2003) for alcohol abuse, and that LS individuals' P3 responses could reflect an inherited predisposition for alcohol cues to engage the appetitive motivational system (see Bartholow et al., in press). The purpose of the current experiment was to continue to examine how low sensitivity manifests as a unique risk factor, beyond family history of alcoholism or previous alcohol use, by investigating a possible vulnerability of LS individuals to biased attentional processing of alcohol-related cues.

Spatial cuing paradigms often have been used to investigate the manner in which early attention processes affect visuospatial information processing (Posner & Rothbart, 1980). Typically, one side (either left or right) of the visual field is cued as a likely target location, and then a target appears in either the cued location (i.e., valid trials) or in the uncued location (i.e., invalid trials). Target responses typically are faster for valid than for invalid trials (e.g., Nobre, Sebestyen, & Miniussi, 2000; Posner, Snyder, & Davidson, 1980), indicating that attention had been allocated to the cued locations prior to target onset. Simultaneously, given that attention had been oriented to cued locations, invalid trials require disengaging attention from the current (cued) location and reorienting to the (uncued) target locations, resulting in a slower reaction time.

In the current study, ERPs were used to identify the stage(s) of information processing at which the hypothesized preferential processing of alcohol cues emerges in LS individuals. In particular, biases in processing of alcohol-related cues might arise during initial attention orienting, later attention maintenance/reorienting, or both. Two ERP components are of particular relevance for investigating these two processing stages. First, the posterior, visually evoked P1 component is a positive deflection typically peaking around 100 ms poststimulus and generated in extrastriate cortex (Di Russo, Martinez, Sereno, Pitzalis, & Hillyard, 2001; Hillyard & Anllo-Vento, 1998). In spatial cuing paradigms, the P1 typically is larger for valid than for invalid trials (e.g., Handy, Green, Klein, & Mangun, 2001; Hopfinger & Mangun, 1998; Mangun & Hillyard, 1991), reflecting the location to which attention is oriented.

The second component of interest here has been characterized in experiments in which target waveforms were more negative at sites ipsilateral to the target presentation side for invalid trials relative to valid trials (Hopfinger & Mangun, 2001; Hopfinger & Ries, 2005). This so-called ipsilateral invalid negativity (IIN) is visible at lateral temporal–parietal regions 200–300 ms following target onset. According to neuroimaging and lesion data, posterior temporal–parietal regions are involved in reorienting attention away from invalidly cued locations and toward target locations (Chambers, Payne, Stokes, & Mattingley, 2004; Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Posner, Walker, Friedrich, & Rafal, 1984). Thus, it is presumed that IIN amplitude reflects the extent of attentional disengagement from an invalidly cued location and shifting of attention to a new location (Hopfinger & Mangun, 2001; Hopfinger & Ries, 2005). When a target appears in an uncued hemifield, the hemisphere ipsilateral to the target side is involved in disengaging attention from the cued location and moving attention to the uncued location (in which the target appeared). Conversely, when a target appears in a cued hemifield and attention has been allocated to the cued side, no disengagement and reorienting of attention are needed and thus no IIN should be visible.

In the current study, alcoholic and nonalcoholic beverage cues were presented simultaneously, one to the left and one to the right side of fixation. Targets were presented either in the same location as the preceding alcohol cue (AT condition) or as the preceding nonalcohol cue (NAT condition). Given that motivationally salient stimuli tend to capture attention (Engelmann & Pessoa, 2007), and that alcohol cues appear to have particular motivational significance for LS individuals (Bartholow et al., 2007, in press), we predicted that LS individuals' attention would be biased toward alcohol cues, as indicated by (a) faster responses to targets in the AT than in the NAT condition; (b) larger target-evoked P1 for AT trials than for NAT trials (due to spontaneous attention capture by alcohol cues); and (c) no IIN on AT trials but a robust IIN on NAT trials, reflecting LS participants' maintenance of early orienting and difficulty disengaging from alcohol-cued locations. Moreover, if low sensitivity represents a risk factor distinct from previous alcohol use and familial alcoholism (see Bartholow et al., 2007), these predictions should hold irrespective of differences in recent alcohol consumption or family history. Figure 1 illustrates this predicted alcohol-related attentional bias for LS participants.

Method

Participants

Forty-six undergraduates (22 women) at the University of Missouri reporting no history of major medical or psychiatric disorders participated in exchange for course credit. Participants were recruited on the basis of self-reported sensitivity to the effects of alcohol using five items from the Alcohol Sensitivity Questionnaire (see next section) that previous work has indicated best differentiate HS and LS individuals (Williams, Sher, & Bartholow, 2009), which were administered during a mass Web-based survey completed several weeks prior to the experiment. Respondents whose preliminary sensitivity scores

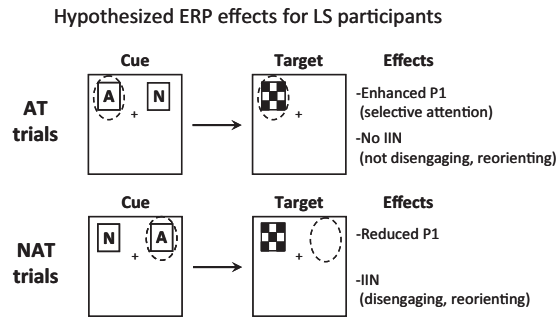

Figure 1. A schematic depiction of the conditions and predicted attention bias for alcohol cues among low-sensitivity (LS) participants. The dashed ovals represent the locations to which participants presumably attend. Biased attention to alcohol cues would be evident if (a) the P1 is enhanced and the ipsilateral invalid negativity (IIN) is absent when targets appear in alcohol-cued locations (AT trials); and (b) the P1 is reduced and a robust IIN occurs when targets appear in non–alcohol-cued locations (NAT trials). A = alcohol cues; N = nonalcohol cues.

Table 1
Mean Alcohol Sensitivity and Alcohol Use and Problems Scores (and Standard Deviations) of the Low-Sensitivity (LS) and High-Sensitivity (HS) Participants Whose Data Were Used for Statistical Analyses

	LS (n = 17)		HS (n = 17)		
Variable	Men (n = 11)	Women (n = 6)	Men (n = 10)	Women (n = 7)	Sensitivity effect
Alcohol sensitivity	10.17 (2.05)	7.93 (1.88)	4.11 (1.47)	3.75 (1.25)	
Drinking quantity	9.86 (2.78)	6.17 (2.77)	3.30 (2.45)	3.42 (1.99)	$t(32) = 5.17^*$
Drinking frequency	3.50 (1.30)	2.18 (1.82)	0.68 (0.58)	1.51 (1.20)	$t(32) = 4.02^*$
Drinking Q/F	34.43 (18.72)	15.34 (16.91)	2.93 (3.75)	5.94 (6.99)	$t(32) = 4.33^*$
Alcohol problems	11.45 (7.10)	8.27 (5.90)	2.94 (4.18)	8.40 (12.35)	$t(32) = 1.55$

Note. Larger alcohol sensitivity scores indicate lower sensitivity (i.e., more drinks required to experience given effects from drinking alcohol). Drinking quantity = average number of drinks consumed per occasion in the past month; Drinking frequency = average number of drinking occasions per week in the past month; Drinking Q/F = drinking quantity/frequency composite (Drinking Quantity × Drinking Frequency). The sensitivity effect represents the magnitude of the difference in alcohol use and problems means between LS and HS participants.
$^* p < .05$.

fell within the lower 25% of all responses (i.e., needing fewer drinks to experience alcohol-related effects) were recruited for the potential HS group; those whose responses fell within the upper 25% were recruited for the potential LS group.

Self-Report Measures

Alcohol Sensitivity Questionnaire (ASQ). On their arrival at the lab, participants' sensitivity to the effects of alcohol was measured with the entire 16-item ASQ (O'Neill, Sher, & Bartholow, 2002; see also Bartholow et al., 2007, in press). The first 10 items relate to experiences typically associated with the ascending limb of the blood alcohol concentration (BAC) curve, such as feeling high or "buzzed," becoming more talkative, more flirtatious, and so forth (i.e., positive, stimulating effects). For each item, respondents first indicate whether they have ever experienced the given effect (e.g., "Do you ever become more talkative after drinking alcohol?"); if they have, they estimate the *minimum* number of standard drinks they could consume before experiencing that effect. The remaining six items tap experiences typically associated with the descending limb of the BAC curve, such as feeling nauseated, vomiting, or passing out (i.e., negative, sedating effects). These items are structured like the first 10, except that participants estimate the *maximum* number of standard drinks they could consume without experiencing the effect. An overall sensitivity score is calculated by averaging the number of drinks a participant reports across all effects (here, $\alpha = .94$). For each participant, a given item is included in their score only if he or she endorses that effect. Given that men generally report lower sensitivity than women, ASQ scores were stratified by sex to ensure roughly equal representation of men and women in the sample. Within-sex median splits (of the ASQ score) were used to determine HS and LS groups. Table 1 shows mean alcohol sensitivity scores of men and women included in the HS and LS groups.[1]

Alcohol use and problems. Participants were asked to report their alcohol use within the past 30 days by estimating the number of drinks they typically consumed per occasion (quantity) and the number of drinking occasions they typically experienced per week (frequency; see Table 1). For current purposes, a drinking quantity/frequency composite (drinking Q/F) was computed as the product of each participant's drinking quantity and frequency scores. Participants also completed a 24-item measure of alcohol-related negative consequences (e.g., "Have you been arrested for drunken driving or driving while intoxicated?") and alcohol abuse or dependence symptoms (e.g., "Have you had 'the shakes' after stopping or cutting down on drinking?"). Response options included *never*; *yes, but not in the past year*; *in the past year but not in the past 3 months*; and *yes, in the past 3 months: once, twice, 3 times, 4+ times* (scored 0, .3, .5, 1, 2, 3, and 5, respectively). An alcohol problems index was computed for each participant as the sum of scores across all 24 items ($\alpha = .87$; see Table 1).

Family history of alcoholism. Familial risk for alcoholism was assessed using Mann, Sobell, Sobell, and Pavin's (1985) family tree questionnaire. Participants list each of their first- and second-degree relatives and indicate for each one whether they are (or were) a nondrinker, a nonproblem drinker, or have experienced problems from drinking. For current purposes, participants were considered to be at increased familial risk if any first- or second-degree relatives were identified as having an alcohol problem (n = 21) and at low familial risk if no relatives were identified as such (n = 25).

Modified Dot-Probe Task

A computerized task was used to assess biased allocation of attention to alcohol cues. Participants were asked to focus on a black

[1] To ensure that any differences in attention to alcohol cues between HS and LS participants could not be attributable to differences in the valence of alcohol effects endorsed by each group, we examined the total number of positive and negative alcohol effect items endorsed on the ASQ using a 2 (group) × 2 (sex) × 2 (item valence) ANCOVA, including the drinking Q/F composite variable as a covariate. A main effect of group indicated that LS participants generally endorsed more items of both types than HS participants, $F(1, 26) = 12.03$, $p < .01$. The Group × Item Valence interaction was not significant, $F(1, 26) = 1.43$, $p = .24$. However, it is interesting to note that LS participants as a group endorsed many more negative items (105) than did HS participants (72), whereas positive item endorsement was more similar between groups (87 and 77, respectively). Thus, any evidence of biased attention to alcohol cues among LS participants cannot be attributed to LS individuals experiencing more positive or fewer negative alcohol effects than HS participants.

fixation cross shown on a gray background presented in the upper center of the screen, which remained throughout the task. On each trial, pictures of one alcoholic beverage (e.g., beer bottle, wine glass) and one nonalcoholic beverage (e.g., lemonade, water) were presented simultaneously in the upper left and upper right corners of the screen for 250 ms. These cues were followed 268 ms later by a target (i.e., stimulus onset asynchrony was 518 ms), shown for 50 ms. Targets consisted of a blue and white or green and white 3 × 3 checkerboard pattern that appeared in one of the spaces previously occupied by a beverage cue. The participants' task was to categorize the target's color by pressing a key with the index or middle finger of their right hand (counterbalanced across participants) as quickly as possible. The intertrial interval was 1,000 ms. The task consisted of 640 trials. However, only 448 of these trials included a target; the remaining 192 trials were cue-only trials included to reduce response-related anticipatory processes. An equal proportion of alcohol and nonalcohol cues, and blue and green targets, appeared on the left and right sides of fixation.

ERP Recording and Data Analysis

Electroencephalographic (EEG) data were recorded from 29 standard scalp locations (American Encephalographic Society, 1994) using an electrode cap (Electro-cap International, Eaton, OH). Electrodes (tin) were referenced online to the right mastoid and an average mastoid reference was derived offline. The recording locations included five midline sites (Fz, FCz, Cz, CPz, and Pz), 12 lateral sites to the left of the midline (Fp1, F3, FC3, FT7, C3, T3, CP3, TP7, P3, T5, O1, and left mastoid), and their homologous sites to the right of midline. Vertical and horizontal eye movements were monitored using electrodes placed above and below the left eye and 2 cm external to the outer canthus of each eye, respectively. EEG and EOG signals were amplified with a Neuroscan Synamps amplifier (Compumedics, Inc., Charlotte, NC) and filtered online at 0.05 to 30 Hz at a sampling rate of 500 Hz. Impedances were maintained at or below 5 kΩ. Blinks measured at the vertical eye movement channel were corrected from the EEG using a regression-based procedure (Semlitsch, Anderer, Schuster, & Preesslich, 1986). Epochs with horizontal eye movements exceeding ± 25 μV between the 100-ms prestimulus and 400-ms poststimulus and those containing scalp and mastoid potentials exceeding 100 μV were excluded from analyses prior to averaging waveforms according to participant, electrode, and stimulus conditions. Only waveforms obtained during correct-response trials were included in the averages.

For the P1 analysis, we selected four electrodes located in the temporal–occipital areas (T5, T6, O1, and O2) as these were the locations at which P1 effects were largest, consistent with previous work (e.g., Hopfinger & Mangun, 1998). We averaged potentials combined for the left-side and right-side locations and measured mean amplitudes within a time window between 124 and 166 ms poststimulus, which represents 20 ms before and after average P1 peak latency. The IIN is reported to be largest at lateral temporal–parietal sites (e.g., Hopfinger & Ries, 2005), which was the case here. Thus, IIN analyses focused on the waveforms obtained at the T5 and T6 electrodes. The IIN was computed as the average amplitude within 220–280 ms poststimulus (30 ms before and after average peak latency) at electrodes ipsilateral to the target side.

Table 2
Least Squares Mean Reaction Times (RT) and P1 and Ipsilateral Invalid Negativity (IIN) Amplitudes, Adjusted for the Drinking Quantity/Frequency Composite, as a Function of Group and Trial Type

Variable	Trial type	LS (n = 17)	HS (n = 17)
RT (ms)	AT	516.54 (57.31)	514.61 (44.71)
	NAT	522.59 (55.89)	510.13 (43.11)
P1 (μV)	AT	3.36 (2.29)	3.67 (2.35)
	NAT	2.93 (2.26)	3.85 (2.48)
IIN (μV)	AT	2.89 (2.29)	1.88 (2.24)
	NAT	2.09 (1.94)	1.83 (2.19)

Note. Numbers in parentheses are standard deviations. LS = low-sensitivity individuals; HS = high-sensitivity individuals; AT = targets appearing on the alcohol-cued side; NAT = targets appearing on the non–alcohol-cued side.

Results

Data from 12 participants were excluded from analyses: six because of blink correction failure, four because of excessive horizontal eye movements, one because of a failure in response time recording, and one because of missing responses to the recent drinking items. Thus, data from 34 participants (17 in each group) were used in statistical analyses.

As shown in Table 1, LS participants reported significantly more recent drinking than HS participants, but the groups did not differ significantly in terms of mean number of alcohol-related problems. Also, as in previous work (Bartholow et al., 2007, in press), LS participants (six at increased risk) were no more likely than HS participants (nine at increased risk) to have familial alcoholism history, $\chi^2(1) = 1.07$, $p = .30$. To determine whether predicted interactions between group and trial type were robust to differences in recent alcohol consumption, drinking Q/F was included in each analysis as a covariate.[2] Behavioral and ERP data were submitted to separate 2 (group: LS, HS) × 2 (sex) × 2 (trial type: AT, NAT) mixed factorial analyses of covariance (ANCOVAs) with repeated measures on the third factor.

Average response accuracy was 95% and did not differ significantly across groups or conditions. Average response times showed the predicted Group × Trial Type interaction, $F(1, 26) = 5.99$, $p < .05$. Least squares means (adjusted for the covariate) associated with this interaction are given in Table 2. Separate paired t tests revealed that LS participants responded more quickly in the AT than in the NAT condition, $t(16) = 2.34$, $p < .05$, but that HS participants' responses did not differ reliably by condition, $t(16) = -1.17$, *ns*.

The waveforms shown in Figure 2 suggest that the P1 was larger in the AT than in the NAT condition for LS participants, but it was larger in the NAT than in the AT condition for HS participants. This apparent group difference was confirmed by a significant

[2] Similar ANCOVAs were conducted using the alcohol problems index and family history score as covariates. As with the analyses presented in the text using the drinking Q/F covariate, controlling for these variables did not eliminate the predicted Group × Trial Type interactions for any of the dependent variables. Also, there were no significant interactions between sex and other predictors in any of the models.

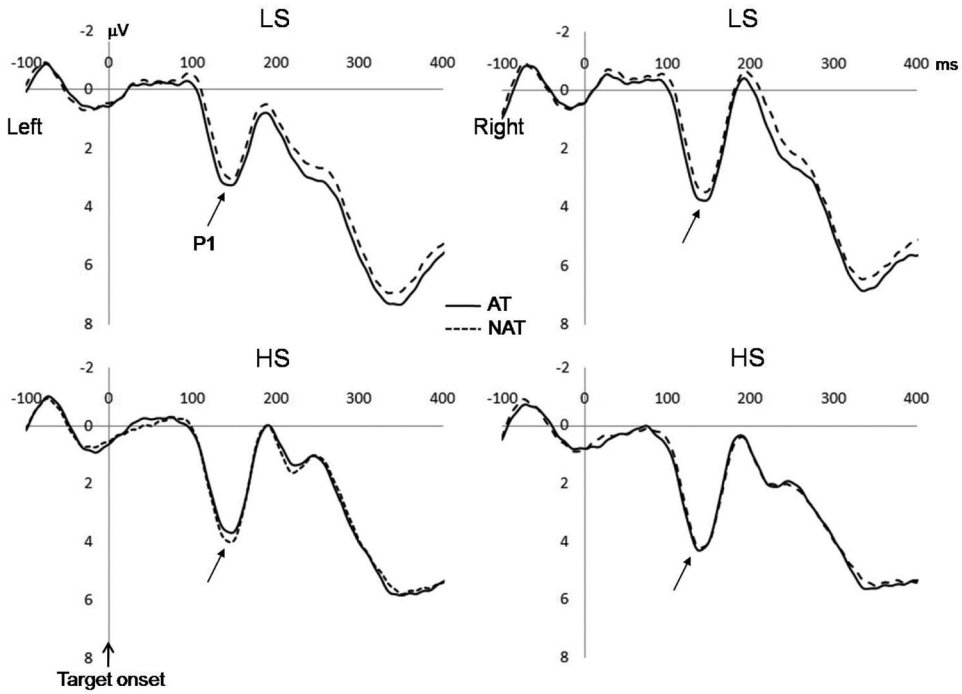

Figure 2. Grand-average event-related potentials (ERPs) elicited by targets at parietal–occipital electrodes as a function of trial type and sensitivity group. The waveforms shown here were averaged for the left and right electrodes separately. The arrows indicate the P1 component. LS = low-sensitivity individuals; HS = high-sensitivity individuals; AT = alcohol-cued trials; NAT = non–alcohol-cued trials.

Group × Trial Type interaction, $F(1, 26) = 7.01$, $p < .05$. Separate *t* tests on mean P1 amplitudes within each group showed that the difference between AT and NAT conditions was reliable for LS participants, $t(16) = 2.45$, $p < .05$, but not among HS participants, $t(16) = -0.76$, *ns*. These results suggest that alcohol cues (relative to nonalcohol cues) captured LS participants' attention. No other effects were significant in this analysis.

Waveforms depicting the IIN are shown in Figure 3. The ANCOVA on IIN amplitudes yielded the predicted Group × Trial Type interaction, $F(1, 26) = 7.44$, $p < .05$. Planned contrasts showed that the IIN was significantly larger (more negative-going) in the NAT condition than in the AT condition among LS participants, $t(16) = 3.19$, $p < .01$, but did not differ by condition among HS participants, $t(16) = -0.02$, *ns*. In addition, the analysis revealed a Group × Trial Type × Drinking Q/F interaction, $F(1, 26) = 4.17$, $p = .051$. Figure 4 presents mean IIN amplitudes separately as a function of trial type and drinking Q/F levels for each group.[3] Inspection of the figure shows that whereas LS participants showed the predicted pattern of more negative-going (less positive) IIN on NAT than on AT trials regardless of recent drinking levels, only HS participants whose recent drinking was relatively light showed no difference across trial types (as in Figure 3). In contrast, HS participants whose recent drinking was relatively heavier showed an IIN effect comparable to that of the LS participants.

Discussion

Recent research (e.g., Cox et al., 1999, 2002; Duka & Townshend, 2004; Townshend & Duka, 2001) has indicated that heavy social drinkers and alcoholics show attention biases to alcohol cues. The current study represents the first demonstration of such a bias among individuals at risk for alcohol use disorder because of low sensitivity. LS individuals' elevated risk for developing alcoholism is well established (e.g., Schuckit, 1994; Schuckit & Smith, 2000). Also, recent findings indicate that alcohol cues are more likely to activate appetitive motivational processes in LS than in HS individuals (Bartholow et al., 2007, in press). The current data are consistent with this notion, elucidating a theoretically plausible information-processing mechanism through which LS individuals might pursue and consume more alcohol than their HS peers. That is, LS individuals' attention appears more likely to be drawn to alcohol cues, likely because of their apparent motivational significance for these individuals (Bartholow et al., 2007, in press), which then is likely to initiate appetitive/approach motivational processes that, in theory, are likely to increase consumption (see Robinson & Berridge, 2001). It is important to note that, although our analyses indicate that differences in recent drinking experiences do not account for the effects of low sensitivity on attention bias, it is not necessarily the case that this bias completely precedes experience with alcohol. Rather, it could be that once drinking is initiated (e.g., during adolescence), alcohol-related experiences differentially shape the development of information-processing biases for LS and HS individuals, putting LS individuals on a higher risk trajectory.

[3] Note that, although presentation of this complex, three-way interaction is facilitated by dichotomizing the drinking Q/F variable, in all analyses the continuously scored Q/F variable was used.

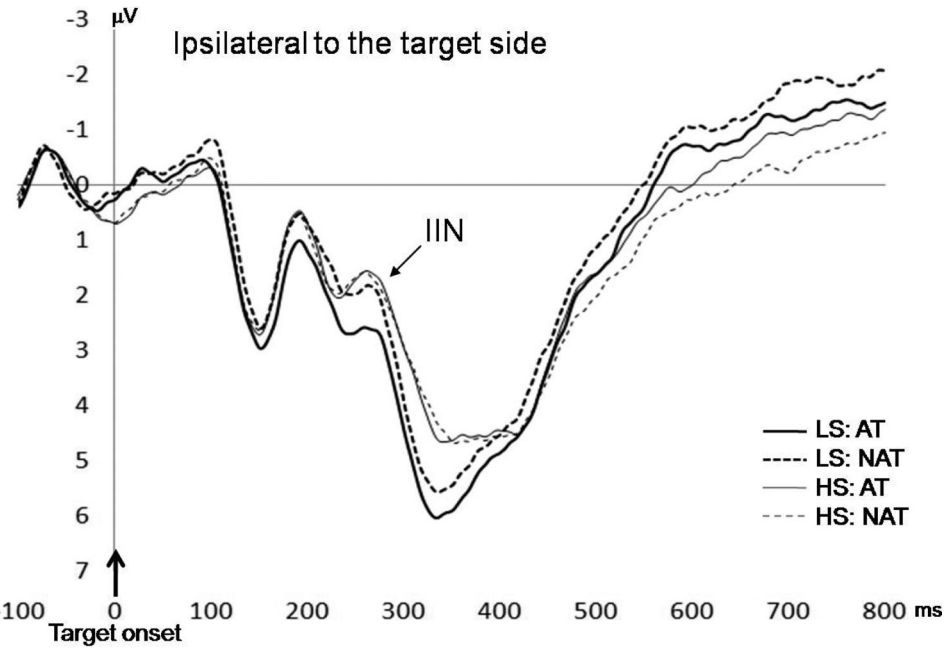

Figure 3. Grand-average event-related potentials (ERPs) elicited by targets at temporal–parietal sites ipsilateral to the target side as a function of trial type and sensitivity group. The arrow indicates the time window of interest, in which ipsilateral invalid negativity (IIN) was observed. LS = low-sensitivity individuals; HS = high-sensitivity individuals; AT = alcohol-cued trials; NAT = non–alcohol-cued trials.

The current ERP data provided evidence of the loci and time course of events within the information-processing system associated with observed behavioral bias effects. Specifically, the P1 response was larger for AT than NAT trials among LS participants, indicating that their attention was captured by alcohol cues very early in processing. Also, the fact that the IIN was smaller (less negative-going) in the AT than the NAT condition for LS participants indicates that their initial orienting bias was maintained during a somewhat later stage (200–300 ms poststimulus). Specifically, LS participants disengaged attention from a current (i.e., alcohol-cued) location and reoriented to the opposite (i.e., target) location on NAT trials, but they simply maintained their current attentional orienting (i.e., to the alcohol-cued location) on AT trials.

Unlike the LS group, HS participants did not preferentially attend to either cued location immediately after cue onset, as indicated by their lack of a trial type effect in the P1 component. However, recent drinking levels influenced later attention mainte-

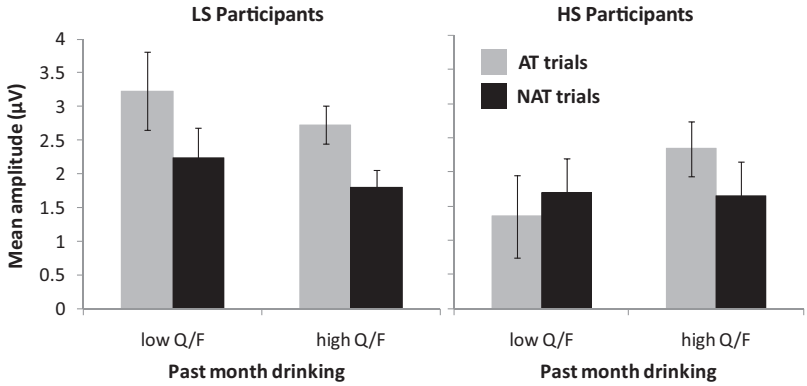

Figure 4. Mean ipsilateral invalid negativity (IIN) amplitudes measured at temporal–parietal sites ipsilateral to the target side as a function of trial type, participant group, and drinking quantity/frequency (Q/F). Vertical bars represent ± standard errors. Note that a less positive mean value indicates a larger (more negative-going) IIN response. Note also that although the drinking Q/F variable was dichotomized (median split) for ease of data presentation, the continuous recent drinking variable was used in the analysis. LS = low-sensitivity individuals; HS = high-sensitivity individuals; AT = alcohol-cued trials; NAT = non–alcohol-cued trials.

nance/reorienting among HS participants. Specifically, the three-way interaction observed in the IIN data suggests that HS participants whose recent drinking was heavier showed evidence of having oriented toward the alcohol cue on AT trials, indicated by their smaller (less negative) IIN on those trials.

The pattern in the IIN data suggests an intriguing possibility concerning different potential routes by which risk for heavy alcohol involvement could manifest via information-processing biases. Specifically, the fact that LS participants' ERP and behavioral responses were unaffected by recent drinking suggests that their bias reflects a more enduring propensity, and is consistent with the recently proposed possibility that electrocortical responses to alcohol cues could represent an endophenotype for alcoholism (see Bartholow et al., in press). In contrast, HS participants' IIN responses were influenced by recent drinking, such that those who drank relatively more in the recent past showed evidence of difficulty reorienting attention away from alcohol-cued locations. This finding suggests that individuals who are not at elevated risk because of low sensitivity can develop information-processing biases via their drinking behavior.

LaBerge (2001, 2002) proposed a neurocircuit theory of attention, which accounts for the roles of different cortical areas in modulating brief (i.e., orienting) and sustained (i.e., maintenance) attention. According to this theory, attention is sustained via motivational regulation of attention control when stimuli are motivationally significant in some manner. The current P1 and IIN data nicely fit within this framework. Specifically, the brief attention-orienting effect reflected in the P1 suggests more consistent orienting to alcohol cues among LS than HS participants. Moreover, the IIN data indicated that attention was consistently sustained in the AT condition among LS participants, supporting the notion that the regulation of attention among LS individuals was modulated by the motivational significance of alcohol cues.

We have argued that this motivational salience among LS individuals reflects a potential genetic vulnerability (Bartholow et al., 2007, in press; see also Heath et al., 1999; Schuckit et al., 2001). However, it should be acknowledged that to date evidence supporting this contention is sparse, and some part of this effect could reflect an acquired response (although not necessarily because of consumption history). In addition, the fact that sensitivity level and family history of alcoholism appear either uncorrelated (as in this case; see also Bartholow et al., 2007, in press) or only modestly correlated (e.g., see Schuckit & Smith, 2000) suggests that any genetic component of sensitivity would only partially overlap with factors that manifest in family members' alcohol-related problems. Recent theorizing (Newlin & Renton, 2010; Schuckit, Smith, & Trim, 2010) and reviews (Newlin & Thompson, 1990) indicating that vulnerability associated with family history and that associated with low sensitivity manifest differentially on the ascending and descending limbs of the BAC curve, respectively, suggest one important way in which expression of these two risk pathways differs.

In conclusion, the current findings indicate that LS individuals have a bias in attending preferentially to alcohol-related cues. This bias cannot be attributed to differences in recent alcohol use, alcohol-related problems, or family history of alcoholism. Thus, these findings suggest a possible route by which LS individuals are prone to increased alcohol use. Regardless of whether attentional bias is inherited or acquired, the current findings, coupled with other recent work addressing the clinical significance of the incentive salience of drug cues (e.g., Cox et al., 2002; Field & Eastwood, 2005), support attentional retraining interventions aimed at rectifying alcohol-related cognitive biases by prohibiting attention allocation to alcohol cues or redirecting attention to nonalcohol stimuli (see Wiers et al., 2006).

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