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BRIEF REPORT

Alcohol-Related Visual Cues Impede the Ability to Process Auditory Information: Seeing but Not Hearing

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Studies of visual attention find that drinkers spend more time attending to images of alcohol-related stimuli compared to neutral images. It is believed that this attentional bias contributes to the maintenance of alcohol use. However, no research has examined the possibility that this bias of visual attention might actually impede the functioning of other modalities, such as the processing of accompanying auditory stimuli. This study aimed to determine if alcohol-related images engender greater sensory dominance than neutral images, such that processing accompanying information from another modality (audition) would be impeded. Drinkers who had an attentional bias to alcohol-related images performed a multisensory perception task that measured how alcohol-related versus neutral visual images affected their ability to detect and respond to simultaneously presented auditory signals. In accord with the hypothesis, compared with neutral images, the presentation of alcohol-related images impaired the ability to detect and respond to auditory signals. Increased dominance of the visual modality was demonstrated by more bimodal targets being misclassified as visual-only targets in the alcohol target condition compared with that of the neutral. Findings suggest that increased processing of alcohol-related stimuli may impede an individual's ability to encode and interpret information obtained from other sensory modalities.

Keywords: attentional bias, alcohol, multisensory perception, visual dominance, redundant signal

The ability of drug-related cues to evoke behavioral and physiological reactions in drug users has long been considered an important mechanism in the development and maintenance of drug addiction (Siegel, 1975; Wikler, 1973). Recent research has focused on the increased attention that heavy drinkers allocate to alcohol-related cues, and how such an "attentional bias" toward alcohol-related stimuli could play an important role in the development of alcohol abuse due to the acquisition of incentive salience in such cues (for a review, see Field & Cox, 2008).

In the laboratory, attentional bias to alcohol is typically measured using visual probe tasks in which participants press a key in response to probes that appear in the location of one of two previously presented images: an alcohol-related and a neutral image (Ehrman et al., 2002). The general finding from this task is that alcohol drinkers display greater bias in the form of increased reaction time (RT) and longer fixation times to alcohol cues than neutral ones (Field & Cox, 2008; Miller & Fillmore, 2010; Schoenmakers, Wiers, & Field, 2008; Weafer & Fillmore, 2013).

It is not known if attentional bias to visual cues for alcohol might affect the ability to efficiently process other information. Limited capacity theories argue that tasks or stimuli that demand increased attention limit the individual's ability to allocate attention elsewhere (Pashler, 1994). Such increased attentional demand from visual cues might limit the ability to attend to or process other information that is simultaneously delivered to other modalities, such as auditory information. Stimuli in our environment regularly provide multisensory combinations of visual and auditory signals to be integrated in order to respond appropriately. Everyday technologies emit simultaneous, "redundant," presentations of visual and auditory signals (e.g., warning lights and sounds) that alert or orient us to respond. Research shows that such multisensory stimuli can facilitate or impair performance, depending on the circumstance (Sinnett, Soto-Faraco, & Spence, 2008).

With regard to the facilitation of performance, certain aspects of behavior, such as RT, may be facilitated through bimodal presentation. Target detection studies have shown that individuals respond more quickly to targets when they are presented as bimodal stimuli (e.g., a light accompanied with a tone) than either modality in isolation. This observation is referred to as the *redundant signal effect* (RSE) and involves intersensory coactivation between the visual and auditory channels (Todd, 1912). However, there is also evidence that redundant stimuli can actually impair performance as

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the modalities compete for information processing resources (Colavita, 1974; Sinnett, Spence, & Soto-Faraco, 2007, 2008). The Colavita effect refers to the sensory dominance of the visual over the auditory modality. Evidence for the Colavita effect comes from classification tasks where subjects must classify target stimuli according to their mode of presentation: visual, aural, or bimodal. Classification errors of bimodal stimuli show that subjects most often misclassify bimodal targets as visual opposed to aural, thus demonstrating the dominance of the visual modality.

The present study sought to examine the degree to which attentional bias to alcohol-related images could impair processing of accompanying auditory information. The heightened visual attention that drinkers allocate to alcohol-related images could affect responding to bimodal stimuli in two important ways. First, attentional bias to alcohol could augment the Colavita effect because drinkers should misclassify bimodal stimuli as being "visual-only" more often when the visual component is an alcohol image compared with a neutral image. Second, attentional bias to alcohol could reduce RSE as the heightened attention to visual images of alcohol might limit attendance to, and therefore coactivation from, any accompanying auditory signal. These hypotheses were tested using a multisensory RT task that measured the degree to which alcohol-related visual images affected processing of accompanying auditory signals in terms of increased classification errors and reduced RSE. A visual dot probe task was also used in the study to independently verify that the participants displayed attentional bias.

Method

Participants

Twenty-five adults (12 men and 13 women) between the ages of 21 and 33 years participated in this study (mean age = 25.4, *SD* = 3.5). The racial make-up was as follows: Asian ($n = 1$), African American ($n = 4$), Latino/Hispanic ($n = 3$), and Caucasian ($n = 16$) and other, not specified ($n = 1$). Volunteers responded to fliers or Internet postings advertising for social drinkers interested in participating in a study examining the relation between alcohol use and mental and behavioral performance. Inclusion criteria included being of legal drinking age, reporting a weekly frequency of alcohol use, normal or corrected vision, and no hearing impairments.

Materials and Measures

Multisensory task. The multisensory task is a RT task used to test visual dominance effects and RSEs on responses to stimuli presented to different modalities. The task was based on a version reported previously by Sinnett et al. (2008) and was operated on a computer and controlled by E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). Stimuli consisted of 30 visual images and 20 brief 1-s audio clips. Visual stimuli consisted of 10 images of alcohol (alcohol targets), 10 images of office supplies (neutral targets), and 10 images of other neutral, nontarget images. Alcohol targets ranged from a mug of beer to a shot glass, and office supplies consisted of objects such as a stapler or a calculator. Nontarget images were objects such as a pair of boots or a flower and contained no alcohol or office-related content. The auditory stimuli were unique and included brief sounds such as a bell ring and a cat meow.

Participants were exposed to a series of trials in which a visual stimulus was presented simultaneously with an auditory stimulus on every trial (see Figure 1). Each visual-audio stimulus pair was presented for 1 s separated by a 200 ms intertrial interval that displayed a fixation point. A test consisted of 300 trials. Sixty trials contained targets that were either (a) a visual stimulus (i.e., an alcohol image), (b) an auditory stimulus (i.e., a horse neigh), or (c) both targets together (alcohol image and horse neigh), with 20 trials for each. Two hundred forty trials were nontarget trials where

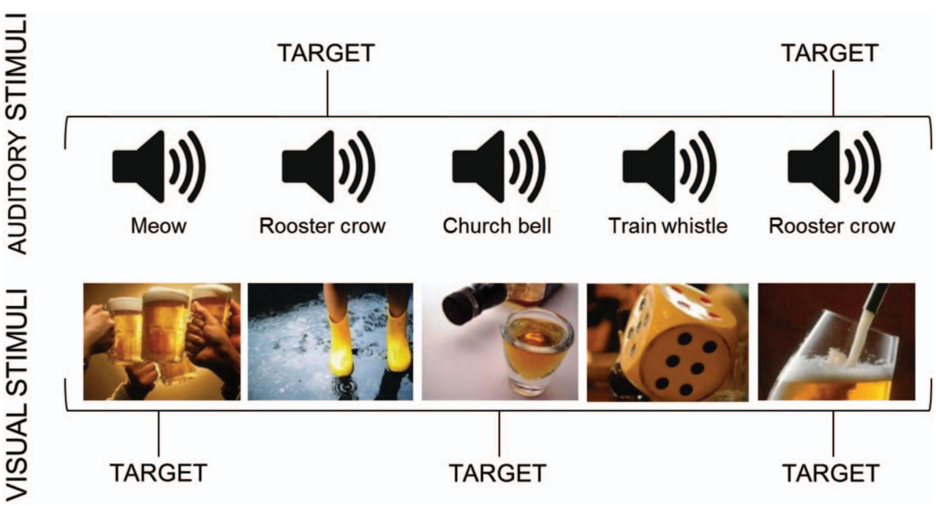

Figure 1. Diagram of trials in the multisensory task for alcohol-related targets. Each column of speaker and photograph pairings represents one trial. Trials are presented as a constant, rapid stream of visual/auditory stimuli pairings throughout the task. In each trial, participants may be presented with a visual target, an aural target, both targets simultaneously or no targets at all. See the online article for the color version of this figure.

neither the visual nor the auditory stimuli were targets. The 60 target trials were presented pseudorandomly among the nontarget trials so as to prevent predictability.

Depending on the test, subjects were instructed to respond to either alcohol or neutral (i.e., office supplies) images as targets. In addition to detecting one or the other set of visual images as targets, participants also were instructed to listen and detect one of the 20 audio clips (see Figure 1). Target detection was indicated by pressing the *1* key on the keyboard anytime a trial contained a visual target, an auditory target, or a visual and auditory target presented simultaneously on the same trial (a "bimodal" target trial).

In addition to the detection version of the task described above, participants also performed a classification version. In this version, the stimulus presentation was identical to the detection version, but participants were to press one of three different keys to classify the modality of the target(s) in a trial. Participants classified target trials as being (a) visual, (b) auditory, or (c) bimodal. For example, if a visual target (i.e., a pitcher of beer) was presented with a nontarget auditory stimulus, the participant would respond by pressing the *1* key on the keyboard. If a bimodal target was presented (i.e., an image of a wine glass and the sound of a horse neighing) then the participant responded by pressing the *3* key on the keyboard. In the detection version, the primary measure was RT. In the classification version of the task, the primary measure was errors in classification.

Visual dot probe task. This task measured attentional bias toward alcohol-related images. Participants viewed a neutral and alcohol-related image presented side-by-side on a computer monitor for 1,000 ms. Upon offset of the images, a visual-probe appeared which participants responded to by pressing a key corresponding to the probe's location. The pictures consisted of 10 alcohol-related images (alcohol beverages) that were paired with 10 neutral images (nonalcohol beverages). The task also included additional "filler" trials that consisted of 10 pairs of nonbeverage neutral images to reduce the likelihood of habituation to the alcohol stimuli. Each pair was presented four times, totaling 80 trials. Fixations were measured using a Tobii T120 Eye Tracking Monitor (Tobii Technology, Danderyd, Sweden). For each trial, we calculated the total duration of all fixations directed toward each image type (i.e., alcohol and neutral images). These values were averaged across trials to produce a mean fixation time for each image type. For a more detailed description of the visual dot probe task, refer to Weafer and Fillmore (2013).

Drinking habits. Drinking habits were obtained using the timeline follow-back, a self-report calendar of drinking for the past 90 days (Sobell & Sobell, 1992). Participants estimated the number of drinks they consumed and over how many hours for each of the 90 days. Fours measures were obtained: (a) binge days, (b) drinking days, (c) total drinks consumed, and (d) days which an individual felt drunk (drunk days). The Alcohol Use Disorders Identification Test was used as an additional measure of drinking habits, (Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). Scores on this measure can range from 0 (*no alcohol-related problems*) to 40 (*severe problems*).

Procedure

Participants performed the multisensory task under two different visual target conditions. In one visual target condition, subjects were instructed to respond to alcohol images (alcohol target condition) and in the other target condition subjects responded to images of office stationery (neutral target condition). Participants also were required to respond to an auditory stimulus unique to each condition. Each target condition was performed twice in the same session: once for each the detection and classification versions. Thus, subjects performed four tests: two target conditions (alcohol or neutral) crossed with two response versions (detection and classification). The study involved two test sessions conducted on two different days. Testing in each target condition (alcohol and neutral) occurred on different days. The order of target condition was counterbalanced across subjects. The only additional task participants were asked to complete in this study was the visual dot probe task. The intersession period ranged from 3 days to 2 weeks.

At the start of the first session, informed consent was obtained, followed by completion of questionnaires about drinking habit and general health. A zero blood alcohol content was verified by a breath analysis. Participants then performed the visual dot probe task. They were then acquainted with the multisensory task and were assigned to one of two target conditions for the test session (alcohol or neutral targets). They then completed the detection version and classification version of the task. At the start of the second session, a zero blood alcohol content was once again verified. Participants then performed the multisensory task with same instructions as in session one, but responded to the other target condition. At the conclusion of the session participants were paid and debriefed.

Criterion Measures and Data Analyses

Multisensory task: Classification version. The visual dominance effect was measured by the number of classification errors made to the 20 bimodal target trials. The number of bimodal targets that a subject misclassified as being visual-only targets was the measure of visual dominance. A larger number of bimodal misclassifications as being visual-only versus auditory-only targets (i.e., a positive difference score) is considered to represent the dominance of the visual modality. The prediction that visual dominance would be greater in the alcohol versus neutral target condition was tested by a 2 (Target Condition: alcohol vs. neutral) $\times$ 2 (Misclassification Type: visual-only vs. auditory-only) repeated-measures analysis of variance (ANOVA) of misclassification errors to the bimodal stimuli.

Multisensory task: Detection version. The RSE was measured by RT differences between the visual and bimodal modalities. A participant's mean RT to detect visual targets was compared to their time to detect bimodal targets. The RSE is indicated by shortened RT to bimodal versus visual targets (negative difference score). The hypothesis that the magnitude of this RSE would be reduced in the alcohol compared with neutral target condition was tested by with a 2 (Target Condition: alcohol vs. neutral) $\times$ 2 (Modality: bimodal vs. visual) repeated-measures ANOVA of RT. Only RTs between 200 and 1,000 ms were recorded. Response times longer than 1,000 ms were considered omissions and RTs shorter than 200 ms were considered as anticipatory responses.

Attentional bias. Attentional bias on the visual dot probe task was measured by the mean difference in fixation time between alcohol and neutral stimuli were determined, where positive scores were indicative of attentional bias.

Results

Drinking Habits

Participants' self-reported drinking habits are presented in Table 1.

Attentional Bias

Attentional bias scores are plotted in Figure 2. As predicted, a paired-sample t test of attentional bias scores demonstrated a significantly larger fixation time to alcohol targets compared to neutral targets, $t(24) = 3.9$, $p = .001$. Figure 2 illustrates this difference. Therefore, the assumption that this sample had attentional bias to alcohol was supported.

Visual Dominance (Colavita) Effect

Classification errors for each target condition are plotted in Figure 3. The 2 (Target Condition) × 2 (Misclassification Type) ANOVA revealed a significant main effect of misclassification type, $F(1, 24) = 14.0$, $p = .001$, indicating a difference between the number of errors misclassified as being visual-only and auditory-only targets. Moreover, the Target × Misclassification Type interaction was also significant, $F(1, 24) = 7.6$, $p = .011$. Figure 3 illustrates this interaction. In accord with the hypothesis, this figure shows that bimodal targets that contained alcohol images were more likely to be misclassified as being visual-only targets versus auditory-only targets, whereas bimodal targets that contained neutral images were more similar in their likelihood of being misclassified as visual- or auditory-only. Thus, as predicted visual dominance was greater in the alcohol target versus neutral target condition.

There was a mean of 7.6 and 6.6 omissions out of 60 target trials in the alcohol and neutral target conditions respectively. A paired-sample t test indicated no difference in the number of omissions between target conditions, $t(24) = 1.2$, $p > .05$. Paired-sample t tests indicated no difference between the target conditions on total misclassification errors, $t(24) = 1.0$, $p > .05$. The effects of target order (alcohol first vs. neutral) on misclassification of bimodal target was also examined in a 2 (Target Condition) × 2 (Misclassification Type) × 2 (Target Order) ANOVA, with no significant main effect or interaction involving target order, $ps > .05$.

Table 1
Self-Reported Drinking Habits

Drinking habit measure	*M*	*SD*
TLFB (past 90 days)		
Drinking days	23.9	10.7
Total drinks	95.0	83.6
Binge days	6.2	9.2
Drunk days	6.9	8.4
AUDIT	7.4	4.5

Note. TLFB = timeline follow-back; AUDIT = Alcohol Use Disorders Identification Test.

Redundant Signal Effect

The RSE in each target condition is plotted in Figure 4. The 2 (Target Condition) × 2 (Modality) ANOVA revealed a significant main effect of modality, $F(1, 24) = 99.9$, $p < .001$, and as expected, RTs were faster to redundant versus visual targets. Moreover, the Target Condition × Modality interaction was also significant, $F(1, 24) = 58.6$, $p < .001$. Figure 4 shows that the interaction occurs because the speed advantage produced by the redundant targets was less pronounced for alcohol-related versus neutral targets. Thus, as predicted alcohol-related stimuli reduced the magnitude of the RSE.

Omission errors were infrequent, with a mean of 1.32 and 0.76 omissions out of 60 target trials in the alcohol and neutral target conditions respectively. A paired-sample t test indicated no difference in the number of omissions between target conditions, $t(24) = 1.48$, $p > .05$. The effects of target order on RT was also examined in a 2 (Target Condition) × 2 (Modality) × 2 (Target Order) ANOVA, with no significant main effect or interaction involving target order, $ps > .05$.

Supplemental Analyses

For exploratory purposes, Pearson r correlations between drinking habits and task performance on both versions of the multisensory task were examined to determine if participants reporting heavier drinking habits might also demonstrate a more pronounced visual dominance response to alcohol-related stimuli in the classification task and less gains from redundant signals in the detection task. None of the self-reported measures of drinking habits yielded a significant correlation with either the visual dominance or RSEs on the multisensory task, $ps > .188$. Pearson r correlations between attentional bias scores on the visual probe and an individual's RSE or visual dominance effect scores were also tested for both alcohol and office supply stimuli in the multisensory task. No significant correlation between the RSE or visual dominance effect and attentional bias was found, $ps > .05$.

Discussion

In support of the hypothesis, attentional bias to alcohol images disrupted the ability to process accompanying auditory information. Visual dominance, as indicated by the Colavita effect, was greater for alcohol compared with neutral images. The study also showed that alcohol-related images reduced the magnitude of the RSE. Reduced RSE to alcohol images is consistent with the notion that increased attention to alcohol images limits the ability to attend to accompanying auditory signals, reducing their coactivating effect that would otherwise speed RT. The study also examined if individual differences in the redundant signal visual dominance effects might be related to drinking habits or attentional bias, but no relationship was observed. However, observance of such a relationship might require a broader range of drinkers that includes alcohol dependent drinkers for which alcohol images might have the greatest visual dominance.

A reduced ability to process information in the presence of alcohol-related stimuli could contribute to the decision to drink,

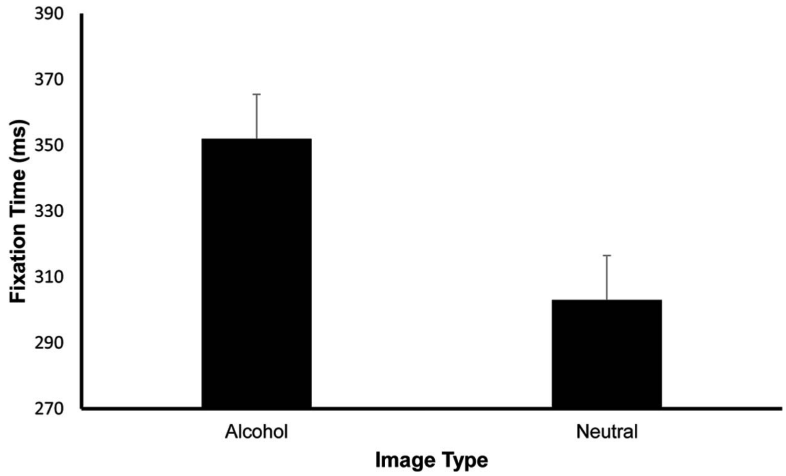

Figure 2. Mean fixation time on visual probe task. The left bar represents average fixation time to alcohol images. The right bar represents mean fixation time to neutral images. Increased fixation time on alcohol images compared to neutral images indicates an attentional bias toward alcohol-related stimuli.

particularly in individuals attempting to reduce their consumption or abstain. By reducing the individual's ability to attend to and process other stimuli in the context, the individual might be less likely to be influenced by other cues in the environment that signal positive outcomes of other behaviors, besides drinking. The net is result is that the drinker is less able to consider alternative courses of action in the situation and instead remains focused on the alcohol cues becoming more likely to act upon those cues and drink.

The increased visual dominance of the alcohol-related stimuli in the study was likely due to their appetitive properties. Appetitive stimuli likely receive increased attention and processing thereby limiting the degree to which accompanying stimuli are encoded or processed. A target condition that is also appetitive, such as images of food, may yield results similar to those of alcohol, particularly for individuals in a deprived state. In particular, it could be determined whether attentional bias and the effects found in this study are due specifically to the stimuli being alcohol or simply the stimuli having appetitive properties.

In conclusion, the study provides emerging new evidence that alcohol-related stimuli not only capture heightened attention but can also disrupt information processing and behavioral control at multiple stages including stimulus encoding. Specifically, the find-

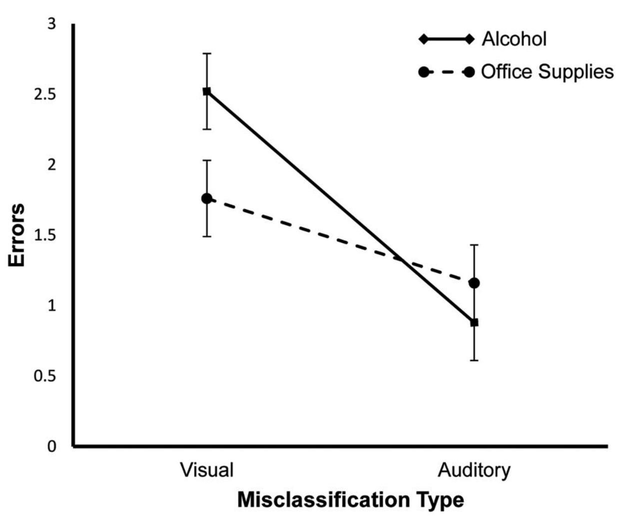

Figure 3. Mean number of classification errors of the bimodal targets in the classification task. The number of bimodal targets misclassified as being visual-only targets was greater in the alcohol target condition compared with the office supplies target condition, indicating that visual dominance was greatest for alcohol targets.

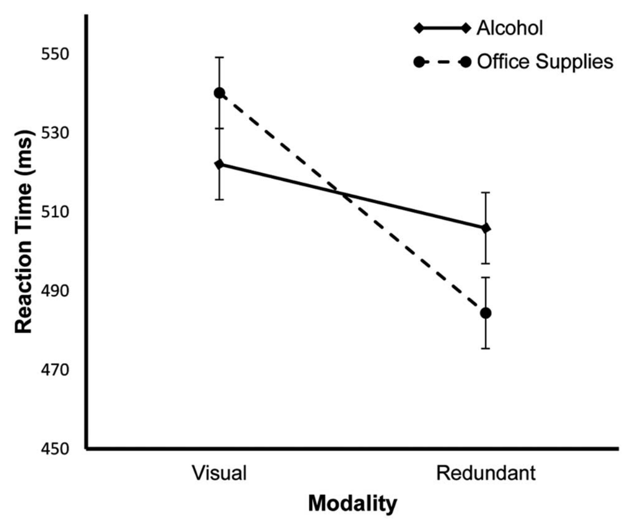

Figure 4. Mean reaction times to redundant and visual modalities in detection task. The speed advantage produced by redundant targets was less pronounced for alcohol-related versus neutral targets, as indicated by the greater difference between visual and redundant reaction times for office supplies compared to alcohol.

ings demonstrate how biased attention to alcohol-related images could impede the ability to process information from auditory sources, with the net effect being a limitation in the scope of information that can be processed at a given time.

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