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The effect of image complexity on attentional bias toward alcohol-related images in adult drinkers

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Abstract

Aim—Visual probe tasks are often used to measure attentional bias (AB) toward alcohol-related images in drinkers, but little is known about the effect of the properties of the images used in this task, specifically, image complexity.

Method—AB was examined in a group of adult drinkers (n = 25). Two measures of attentional bias were obtained from a modified visual probe task. First, a traditional dot probe detection task measured attentional bias in drinkers based on their reaction times to probes replacing neutral and alcohol-related images. Second, an eye-tracking measure was applied to this task to directly assess the drinkers' eye gazes to the alcohol-related and neutral images. The effect of image complexity was examined by comparing AB toward images classified as simple and complex.

Findings—Results showed that drinkers only displayed AB toward simple alcohol-related images as measured by both probe RT and fixation times.

Conclusion—These findings suggest that complex alcohol-related images might be less effective at capturing drinkers' attention and could result in less attentional bias when used in visual probe tasks.

Introduction

It is widely recognized that the effects of abused drugs can be conditioned to the environment in which the drug is consumed [1,2]. Evidence that alcohol-related images can reliably elicit reactions in drinkers has led to studies aimed at testing the possibility that such cues actually come to dominate the drinker's attention. Studies of "attentional bias" concern the degree to which alcohol-related images become the focus of the drinker's attention to the exclusion of other non-alcohol related images. This research employs tasks comparing participants' reaction times to alcohol-related stimuli with matched control stimuli. Chief among these measures is the visual probe task [3,4]. Here, alcohol-related images are matched with control images and pairs of alcohol and control images are individually presented on a computer screen for a brief duration (e.g., 1000 ms). Immediately following the presentation, a visual probe (e.g. an "X") appears in the location previously occupied by either the alcohol-related or the control image and participants must quickly identify the location of the probe by pressing a computer key.

Several studies using the visual probe task find that drinkers react faster to probes associated with the location of alcohol-related images versus control images [5]. The general assumption is that probe detection is faster because the drinker's attention was already

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drawn to the probe's location by the earlier display of the alcohol-related image. Indeed, heavier drinkers show greater attentional bias in this task compared with light drinkers and abstainers [5,6]. In addition, some evidence suggests that attentional bias not only reflects heavier consumption but might also contribute to this pattern of problem drinking. For example, some recent studies have employed strategies to reduce attentional bias toward alcohol-related images in heavy drinkers [7,8] and although findings are inconsistent, some studies have found a subsequent decline in their alcohol use, suggesting the possibility of a causal role [7].

One limitation of the visual probe measure is that facilitation of probe detection requires attendance to the alcohol-related image at the time that the probe appears. However, even during brief exposures, attention can be shifted back and forth between the alcohol-related and control image. Such shifting of attention is likely influenced, in part, by the stimulus duration [9]. Relatively short durations (50–200 ms) are thought to measure biases in initial orienting as participants can only shift attention toward one of the stimuli during the brief presentation. However, when stimulus duration is longer (e.g. greater than 200 ms), participants can make multiple shifts in their attention between the two stimuli, providing a measure of bias that includes the maintenance and/or disengagement of attention [10,11]

Some investigators have examined the role of presentation duration on attentional bias and found the evidence to be mixed [19]. Attentional bias to alcohol-related images has been found in heavy drinkers when images were presented for 500 or 2000 ms but not when the images were presented for a shorter duration [4]. By contrast, others report the opposite effect whereby drinkers displayed a greater attentional bias when the alcohol-related images were presented for a shorter (50 ms) rather than longer (500 ms) duration [12]. Such disparate results might be due to differences in the degree of attentional shifting as a function of presentation durations. However, probe detection RT provides only an indirect assessment of attention allocation and does not account for shifting of attention between images. The present study applied eye-tracking measures to the visual probe task in order to compare alcohol-related and control images in terms of the total time that each image was visually attended to by the subject during a trial. The eye-tracker system was used to examine the subject's gaze in order to quantify the total time spent attending to each image, regardless of the number of times that attention shifted between images. The total gaze time to each image was then compared to evaluate the degree of attentional bias to the alcohol-related image (i.e., greater gaze time toward alcohol images versus control images). Because total gaze time provides a more direct assessment of the degree of total attention allocated to each image during a trial, this measure was compared to the conventional probe RT measure in order to examine the validity of probe RT as a measure of attentional bias.

A second aim of the study was to investigate the role of image complexity on the degree of attentional bias displayed by drinkers. Although the visual probe task has been widely used, to date there has been little attention given to the types of visual cues used to demonstrate attentional bias toward alcohol-related stimuli. In general, studies closely match substance-related and control stimuli on basic perceptual features, such as size, brightness, and overall complexity. However, less attention has been paid to the study of how these attributes, themselves, might affect attentional bias. There is some evidence that the type of visual cues can have an effect on attentional bias. For instance, some studies that have included emotionally laden stimuli have found that alcohol users are more sensitive to emotional stimuli compared with non-abusers [13], which has led some researchers to suggest that stimuli need to be controlled for emotional content [14,15].

Image complexity may be another important dimension of visual images used in attentional bias studies. Visual probe studies present images of varying levels of complexity, from solitary objects, such as a bottle of wine, to more detailed scenes, such as individuals drinking at a bar [5,16]. However, there is no information regarding how such differences in image complexity might influence attentional bias. It is possible that complex images (i.e. a bar or party scene) might be perceived as more realistic representations of individuals' experiences with alcohol. Thus, they might be more effective at capturing attention. However, the converse might also be argued: complex images of alcohol use have many more features and objects present, only some of which are directly alcohol-related (e.g., a few beer bottles in a crowded bar scene). As such, the few alcohol-related objects might be overshadowed by the numerous non-alcohol related stimuli in the image. The present study examined the role of image complexity in attentional bias in order to test these alternative hypotheses.

In sum, studies utilizing visual probe measures provide somewhat inconsistent findings that could be due to parameters, such as image complexity and method in which attentional bias is measured. Given the increased use of the visual probe task as a research tool for assessing alcohol abuse risk, and its more recent use as a potential cognitive intervention for reducing alcohol consumption in problem drinkers [7,8], it is important to better understand task-related factors that could also affect attentional bias. The present study examined attentional bias in a group of healthy non-alcoholic, adult drinkers. Two measures of attentional bias were obtained from a modified visual dot probe task. First, the traditional measure of attentional bias in drinkers was obtained based on their reaction times to probes replacing neutral and alcohol-related images. Second, an eye-tracking measure was obtained during the task to directly assess the drinkers' eye gazes to the alcohol-related and neutral images. This measure assessed attentional bias by comparing the amount of time that visual attention was directed toward alcohol-related versus neutral images. Additionally, image complexity was examined in order to determine how this task dimension might affect the degree of attentional bias that drinkers display.

Methods

Participants

Twenty-five adult drinkers (14 men and 11 women) between the ages of 21 and 35 (mean age = 24.04 years, SD = 3.8) were recruited to participate in this study. Screening measures were conducted to determine medical history and current and past drug and alcohol use. In order to ensure that participants would display some degree of attentional bias to alcohol-related stimuli, we included only participants who reported a minimum drinking regimen of consuming alcohol at least twice per month over the past three months. This inclusion criterion was based on previous findings indicating that attentional bias is found in regular social drinkers and not in non-drinkers or very light, occasional drinkers (e.g., 5, 6). Volunteers were asked a series of specific questions in order to determine their typical drinking habits. Those who reported infrequent drinking (i.e. less than two drinking occasions per month) or who reported a potential risk for alcohol dependence were excluded from participation. Dependence was determined by a score of 5 or higher on the Short Michigan Alcoholism Screening Test (S-MAST) [17]. Any other high-risk indicators of dependence, including prior treatment for an alcohol use disorder or conviction for driving under the influence, also precluded participation in the study. Recent use of benzodiazepines, barbiturates, tetrahydrocannabinol, cocaine, amphetamines, and opiates was assessed through a urine analysis and those who tested positive for the presence of any of these drugs were excluded from participation. These screening measures allowed for the recruitment of adults who regularly consumed alcohol, while excluding infrequent users and those who are dependent on alcohol. Volunteers were recruited via notices placed on community bulletin boards and by university newspaper advertisements. The study was approved by the University of Kentucky Medical Institutional Review Board. Participants received $30 for their participation.

Apparatus and Materials

Visual Probe Task—Attentional bias was measured by a visual dot probe task that was operated using E-prime experiment generation software (Schneider et al., 2002) and performed on a personal computer. Participants were seated in front of the computer monitor with their chins resting in a headrest, which was used to stabilize head movement and maintain a constant eye-to-screen distance of 74 cm. During the task, two 13 cm × 18 cm pictures (a neutral and an alcohol-related image) were presented side-by-side, 3 cm apart, on a computer screen. Upon offset of the picture pair, a visual target appeared. The participant was instructed to respond to the target by pressing one of two response keys on the keyboard to indicate on which side the target appeared. The task compares the reaction times of responding to a target replacing an alcohol-related image versus a target replacing a neutral image and has been used in other research (e.g., 3).

The task stimuli consisted of twenty alcohol-related images that were matched with twenty neutral (i.e. non-alcohol-related) images. Half of the alcohol and neutral images were complex scenes and the other half were simple images. Simple alcohol images depicted a single, solitary image of an alcoholic beverage. These images were matched with simple, neutral images consisting of non-alcoholic drinks (e.g. a can of beer matched with a can of soda). All simple images were photographed against the same background: a bare, neutral colored wall. Complex alcohol images depicted real-life scenes involving alcohol. Examples included bar and party scenes showing people consuming alcohol. These images were matched with complex neutral images that also included groups of people and consumptive activities, such as eating food. A complex alcohol image was always paired with a complex neutral image and a simple alcohol image was always paired with a simple neutral image.

The 20 image pairs were presented four times, once for each of the four possible picture/ target combinations (i.e. left and right picture location and left and right target probe location) for a total of 80 test trials. In addition, there were 80 filler trials which consisted of 20 pairs of neutral images presented four times each. The filler trials are commonly included in tests of attentional bias to reduce possible habituation to alcohol stimuli that might otherwise occur if all trials contained alcohol-related images [5]. The 80 filler trials were randomly intermixed among the 80 test trials for a total of 160 trials.

For each presentation, a fixation point (+) appeared at the center of the screen for 500 ms, followed by a pair of images displayed for 1000 ms. Once the images disappeared, a visual probe (an "X") appeared on the left or right side of the screen, in the position where one of the pictures was previously displayed. Participants were required to press one of two keys (">" or "/") on the keyboard to indicate the location of the target. They had 1000 ms to respond before the probe display was offset and the next trial began.

Eye Tracking—A Model 504 Eye Tracking System (Applied Science Laboratory, Boston MA) was used to measure eye movements during the visual probe task. Eye locations were sampled at 60 Hz and given an X/Y coordinate, which were used to define fixations and saccades. The distance of a saccade and its duration was calculated using fixation onset and offset times. Onsets of fixations were defined as periods of at least 100 ms in which the line of gaze had a standard deviation of less than 0.5 degrees of visual angle. Offsets of fixations were determined by periods of at least 50 ms in which the gaze position was at least 1 degree of visual angle away from the initial fixation position. The final fixation position was the average of all data sampled between the beginning and end of the fixation.

During each trial, total fixation times were calculated for three locations: 1) the alcohol image, 2) the neutral image, and 3) an "off" area, in which the participant's gaze was not fixated on either of the images (for example, the center of the screen). Attentional bias for a trial was determined by the degree to which total fixation time was greater to the alcohol image than to the neutral image.

Timeline follow-back—The timeline follow-back (TLFB; 18) was used to assess participants' drinking habits. The TLFB assesses daily patterns of alcohol consumption over the past 3 months and measures the number of drinks consumed each day during that period. In a semi-structured interview, participants were presented with a calendar of the past 3 months and asked to report how much they drank each day (in standard drinks) working backward from the previous day to three months ago. The administration conformed to procedures outlined by Sobell and Sobell (18). The TLFB provided three measurements of a participant's drinking habits for the past 3 months: 1) total number of drinking days for that period (*drinking days*), 2) total number of drinks consumed in that period (*total drinks*), and 3) total number of days in which participants report being drunk (*drunk days*).

Procedure

Initial Screening—Individuals who responded to the advertisements called the laboratory and were told that the purpose of the experiment was to measure reaction times on a computer task and to evaluate people's drug use history. They then participated in a telephone intake screening interview in which they provided information regarding their drinking practices and only participants whose reported drinking habits met the minimal drinking requirement were invited to participate. Interested volunteers then made appointments to participate in a single laboratory session, which was conducted in the Human Behavioral Pharmacology Laboratory of the Department of Psychology. Once they arrived at the laboratory, participants provided informed consent completed the TLFB. Participants whose drinking habits failed to meet minimal criteria were excluded from participation, paid $10, and thanked for their time. Eligible participants provided urine samples, which were tested for the presence of drug metabolites (On Trak TesTstiks, Roche Dagnostics Corporation, Indianapolis, IN, USA) and HCG (Mainline Confirms HGL, Mainline Technology, Ann Arbor, MI, USA). Breath samples were also provided at the beginning of the session to verify a zero BAC.

Visual probe test—The visual probe task requirements were explained to participants and they became familiar with the task and eye tracking equipment by completing a shortened version of the task consisting of 10 practice trials. This ensured that they understood the requirements of the task and were familiar with the computer and eye tracker. They then performed the full-length visual probe test. Upon completing the test, participants were paid and debriefed.

Criterion Measures and Data Analyses

Probe RT—Mean reaction times to probes were analyzed only for trials in which there was a correct response and for responses that were greater than 100 ms. Incorrect responses were rare and participants' mean proportion of accurate responses was 0.98 (SD = 0.02). Each participant's mean per trial reaction time to probes was calculated for image type (alcohol vs. neutral) and for image complexity (simple vs. complex). This resulted in four reaction time scores for a participant: alcohol-simple, alcohol-complex, neutral-simple, and neutral-complex. Attentional bias was indicated by shorter (i.e. faster) reaction times to alcohol-related versus neutral probes. The reaction times scores were analyzed by a 2 image type (alcohol vs. neutral) × 2 image complexity (simple vs. complex) analysis of variance (ANOVA). A limited set of planned comparisons were performed using *a priori t* tests.

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Fixation time—Each participant's mean per trial fixation time to images was calculated for image type and complexity. Attentional bias was indicated by longer fixation times to alcohol-related versus neutral images. The fixation time scores were analyzed by a 2 (image type) × 2 (image complexity) ANOVA and a limited set of planned comparisons were performed using *a priori t* tests.

Individual differences in attentional bias in relation to alcohol use—Consistent with previous studies of attentional bias (5, 6), heavier drinkers should display greater attentional bias than lighter drinkers. A multiple regression analysis examined the degree to which the magnitude of attentional bias was related to individual differences in the subjects' typical alcohol consumption as measured by the TLFB.

Results

Drinking habits

Table 1 summarizes the participants' drinking habits. Overall, the sample reported frequent alcohol use, drinking on an average of 24.1 (SD = 13.6) days during the past 3 month period, and consuming an average of 6.4 (SD = 3.2) drinks on the days they reported being drunk. Overall, the sample's drinking habits are consistent with those who have demonstrated attentional bias in previous studies (i.e., 5). *t* tests revealed no gender differences on any drinking habit measure (ps > 0.179).

Probe RT

Figure 1 shows the mean reaction times to alcohol and neutral images grouped by image complexity. A 2 (image type) × 2 (image complexity) ANOVA of the RT probe scores revealed a significant main effect of image complexity, F (1, 24) = 36.0, $p < 0.001$, and a significant interaction between image type and image complexity, F (1, 24) = 6.4, $p < 0.05$. Figure 1 shows that participants responded more quickly to simple versus complex images. Moreover, for simple images, attentional bias was evident as participants responded more quickly to alcohol versus neutral stimuli. This was confirmed by a *t* test that compared the mean RT to alcohol versus neutral images in the simple condition, t (24) = 1.79, $p = 0.04$, $d = 0.36$. By contrast, a *t* test comparing RT to alcohol and neutral stimuli in the complex image condition revealed no significant difference (p = 0.15). Thus there was no evidence of attentional bias to alcohol-related stimuli in the complex image condition.

Fixation time

Figure 2 plots the mean gaze times during the visual probe task to alcohol and neutral images classified by image complexity. A 2 (image type) × 2 (image complexity) ANOVA revealed significant main effects of image type, F(1, 24) = 6.39, $p < 0.05$, and image complexity, F(1, 24) = 27.97, $p < 0.001$. The ANOVA also revealed a significant image type by image complexity interaction, F(1, 24) = 15.03, $p < 0.01$. Figure 2 shows that for simple images fixation time was longer for alcohol versus neutral stimuli and this difference was confirmed by a *t* test comparison, t (24) = 3.72, $p < 0.01$, $d = 0.75$. By contrast, for complex images, no significant difference in fixation time was evident between alcohol and neutral stimuli, $p = 0.93$.

Magnitude of attentional bias in relation to drinking habits

Multiple regression analyses tested the relationship of participants' drinking habits to their degree of attentional bias to alcohol in the simple image condition. The magnitude of attentional bias was calculated for each participant as the mean fixation time differences between alcohol and neutral images and as the mean probe RT differences between the alcohol and neutral images. The three TLFB measures were regressed together onto participants' attentional bias scores. Together, the TLFB measures accounted for 42% of the variance in the magnitude of participants' attentional bias to alcohol as measured by the fixation scores, $F(1, 21) = 5.09$, $p < 0.01$. The individual regression coefficients of the three TLFB measures showed positive slopes, indicating that participants who displayed greater attentional bias also reported consuming more drinks, spending more days drinking, and being drunk more days. The TLFB measures did not account for a significant amount of the variance in attentional bias measured by the probe RT score, $F(1, 21) = 0.77$, $p = 0.47$. However, the individual coefficients of the three drinking measures showed positive slopes. The Beta values of the slopes are presented in Table 1 to indicate the relative strength of each TLFB measure in relation to each measure of attentional bias.

Discussion

This study used a visual probe task to measure the degree to which a group of adult drinkers displayed attentional bias toward alcohol-related images. The task yielded two measures of attentional bias: a probe RT measure and a fixation time measure based on the duration of gaze to images. The effect of image complexity on the degree of attentional bias was also examined by comparing the degree of attentional bias displayed toward alcohol in the simple and complex image conditions. Drinkers displayed a significant level of attentional bias toward alcohol-related images that were simple, but not to alcohol-related images that were complex. The study also found that fixation time provided the most robust indicator of attentional bias. The effect size of attentional bias as measured by participants' fixation time was twice as large as the effect size of attentional bias measured by probe RT. Finally, the study found that the magnitude of attentional bias as measured by fixation time was related to the participants' level of alcohol use, with a greater degree of attentional bias being displayed by the heaviest drinkers (i.e. those who drank more often and consumed more alcohol per drinking occasion).

The finding that a group of frequent, heavy drinkers displayed attentional bias toward alcohol-related stimuli is consistent with previous research [5,6]. However, evidence that attentional bias was only evident in response to simple alcohol-related images and not to complex images is a new finding and raises questions about the importance of imagery in these tasks. One reason for the lack of attentional bias in the complex image condition could be due to the fact that complex images often depict environmental settings, such as social activities involving groups of individuals. This introduces more non-alcohol-related features that could compete for attention and possibly overshadow the alcohol-related aspect of the image. In fact, the probe RT findings are consistent with the idea that complex images required more cognitive processing than did the simple images. Specifically, RT to detect probes was slower to complex images compared with simple images. This detection delay could be due to increased cognitive processing that is demanded by the comparatively richer visual stimuli depicted in the complex images. Second, the richer visual environment of the complex images also appeared to elicit more search and scanning behavior compared with simple images. The fixation data show that overall, participants spent less time fixating on complex images compared with simple images. Visual fixations are defined as periods of at least 100 ms in which the line of gaze is held steady (i.e., has a standard deviation of less than 0.5 degrees of visual angle). The shorter total fixation times to complex images suggest increased scanning behavior elicited by these images such that attention was rarely fixated on any location for as long as 100 ms. In sum, these findings challenge the notion that complex images might be more effective at capturing attention because they represent realistic scenes similar to one's own experiences with alcohol. Rather, the findings suggest that simple alcohol-related images might be more effective at capturing and holding one's attention.

It is also important to consider the findings on image complexity in terms of generalizability to other methods of assessing attentional bias to alcohol. The current findings are based on the visual probe task that compares the amount of attention allocated to an alcohol and neutral image when presented simultaneously. Other models of attentional bias, such as the pictorial Stroop task, also present alcohol-related imagery but differ considerably in how these images are presented and in how attentional bias is assessed. The task measures time to identify image color and shows that color identification is slowed when the image contains alcohol-related features. The assumption is that the attentional bias toward the alcohol-related feature “interferes” with the ability to quickly identify the color of the image. With regard to stimulus properties, some evidence suggests that image complexity does not play a role in attentional bias as assessed by the pictorial Stroop task [19]. Thus, although complexity might be important for detecting attentional bias in visual probe tasks, it might be less important in interference-based assessment of attentional bias.

An additional aim of this study was to compare the magnitude of the attentional bias effect as assessed by the probe RT measure versus a measure based on total fixation time. The study demonstrated considerable agreement between these two measures of attentional bias. Specifically, both measures demonstrated attentional bias toward simple, alcohol-related images and neither demonstrated bias toward complex, alcohol-related images. Others have also found agreement between the eye tracking fixation and probe RT measures of attentional bias. For instance, a study by Schoenmakers et al. [20] found that the amount of time participants spent fixating their gaze on substance-related stimuli was positively related to attentional bias as measured by probe RTs during a visual probe task. However, fixation time may provide a more robust assessment of attentional bias as we found a greater effect size of attentional bias based on fixation time versus probe RT. Moreover, it was the individual differences in the fixation time measure of participants’ attentional bias that showed the greater correspondence to their drinking habits. Additionally, a recent study by Field et al. [21] revealed that eye tracking provided a more sensitive measure of attentional bias toward alcohol-related stimuli than reaction time when correlating bias with subjective craving for the drug. Such findings provide promising support for the use of eye tracking techniques in the assessment of attentional bias.

Evidence that fixation time assessments could yield more robust effects of attentional bias also has important implications for studies that examine factors that influence attentional bias. For instance, there is growing interest in understanding how attentional bias toward alcohol-related images might increase or possibly decrease once the drug is consumed [3]. There is also interest in determining how behavioral and cognitive based treatments can decrease attentional bias to alcohol in alcohol-dependent individuals. Reliable evaluation of the effects of such treatments depends greatly on the ability to observe robust attentional bias effects. Fixation time assessments of attentional bias could help to ensure such reliable demonstrations of the effect.

In conclusion, the present study raises important questions about the nature of the images used to demonstrate attentional bias in alcohol research. Little is known about the possible effects of stimulus properties used in tasks designed to measure attentional bias to alcohol. By analyzing image complexity as well as directly monitoring eye movements, this study provided evidence suggesting that complex images could reduce the ability to detect attentional bias to alcohol-related stimuli. The extent to which findings concerning image complexity might generalize to other substance use for which attentional biases are commonly assessed (e.g., smoking) waits to be explored.

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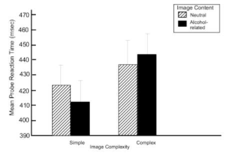

Figure 1.
Mean probe reaction time (ms) to neutral and alcohol-related images presented as either simple or complex. Capped vertical lines indicate standard error of the mean (SEM).

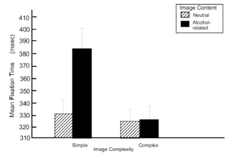

Figure 2.
Mean fixation time (ms) to neutral and alcohol-related pictures presented as either a simple or complex image. Capped vertical lines indicate standard error of the mean (SEM).

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Table 1

TLFB measures of participants' drinking habits. Beta values represent the standardized slope of each TLFB measure when regressed onto fixation and probe RT measures of attentional bias. $N = 25$

			Dependent measure of attentional bias	
			Fixation time	**Probe RT**
	M	***SD***	**β**	**β**
Variable				
Drinking days	24.1	13.6	0.17	0.41
Total drinks	124.4	97.6	0.95	0.57
Drunk days	10.4	10.7	1.45	0.39