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Ocular Imaging of Attentional Bias Among College Students: Automatic and Controlled Processing of Alcohol-Related Scenes*

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ABSTRACT. Objective: Heavy episodic drinking in college is an issue of major concern in our society. In the college setting, where alcohol misuse is prevalent, alcohol-related perceptions and automatic attentional biases may be important determinants in students' decisions to engage in risking drinking behaviors. The current study examined college students' attention to alcohol-related beverages in real time using ocular-imaging techniques. The authors hypothesized that alcohol consumption characteristics such as quantity-frequency of alcohol consumption would predict ocular-imaging indices of attentional bias to alcohol-related images. **Method:** Twenty-six college students successfully completed questionnaires assessing basic demographics and alcohol consumption characteristics, followed by an eye-tracking task in which they viewed pictorial stimuli consisting of photographs of alcohol-related scenes, household objects, or a combination of these items. **Results:** Quantity-frequency index (QFI) of alcohol consumption was positively related to the percentage of initial ocular fixations on the alcohol-related items (r = .62, p = .001), whereas QFI negatively predicted the percentage of initial ocular fixations on the control images (r = -.60, p = .002). In addition, QFI positively predicted participants' dwell time on alcohol-related images (r = .57, p = .005), and negatively predicted dwell time on control images (r = -.41, p = .05). Age at first drink and days since last alcohol consumption were not related to eye-tracking metrics. **Conclusions:** Ocular-imaging methods are a valuable tool for use in the study of attentional bias to alcohol-related images in college drinkers. Further research is needed to determine the potential application of these methods to the prevention and treatment of alcohol misuse on college campuses. (*J. Stud. Alcohol Drugs* **70:** 000-000, 2009)

HEAVY EPISODIC DRINKING IN COLLEGE is a major concern in our society. A recent review of the drinking assessment literature (Devos-Comby and Lange, 2008) reports that at least 40%-45% of college students engage in heavy drinking each year, with around 12%-31% qualifying for a clinical diagnosis of alcohol abuse and 6% qualifying for a clinical diagnosis of alcohol dependence (see also, Knight et al., 2002; Slutske, 2005; Wechsler et al., 2002).

Although previous research has suggested that drinking does not directly correlate with attrition rates on college campuses (Kessler et al., 1995), more recent work has indicated that this result is affected by factors such as students' engagement in extracurricular and group activities (Martinez et al., 2008). When students' event attendance is treated as a suppressor variable in these analyses, heavy drinking *can* predict attrition rates on college campuses. Even more alarmingly, recent statistics report that although youths of all ages are already at a higher risk of traffic fatality compared with older adults, in 2006, 25% of drivers ages 15-20 who were killed in motor vehicle crashes were legally drunk (e.g., had a blood alcohol concentration at or above .08) (National Highway Traffic Safety Administration, 2008; Pedersen and McCarthy, 2008; Zador et al., 2000). Thus, it is important to identify factors influencing college students' decisions to use and/or abuse alcohol, in particular to develop new methods of treatment and prevention of problem drinking in this population.

Despite the fact that alcohol-related attentional bias among social and heavy episodic drinking college students (vs older, alcohol-dependent, community, or treatment-seeking populations) may be subtle, this population provides a crucial link in the understanding of factors related to the development of problem drinking. Thus, any factors that are found to be related to changes (however small) in attentional bias over time in this "at-risk" group could ultimately point to to meaningful targets for intervention.

In the college setting, where alcohol misuse is prevalent, alcohol-related perceptions and attentional biases may be important determinants in students' decisions to engage in risking drinking behaviors. A significant amount of literature exists linking attentional allocation to addiction-related stimuli (e.g., cue reactivity) to various drinking characteristics (Cox et al., 2007; Field et al., 2004b, 2007a,b; Stormark et al., 2000; Townshend and Duka, 2001). According to the Field and Cox (2008) integration of existing theoretical

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models dealing with attentional responses or biases to alcohol-related stimuli and their relationship to behavior (e.g., quantity-frequency of alcohol use, development of alcohol abuse, relapse to alcohol dependence) substance users' cognitive processing of addiction-related stimuli (such as pictures of alcoholic beverages) is a critical component of craving for, and ultimately the use of, addictive substances (such as alcohol). Importantly, the authors note that what constitutes addiction-related stimuli must first be established by experience, so that attentional biases (e.g., cognitive sensitization) to alcohol-related images develop largely as a consequence of classical conditioning (Field and Cox, 2008). Many studies have verified the link between attentional biases to addiction-related stimuli and the development and maintenance of addiction, as well as relapse after periods of abstinence from an addictive substance (Cox et al., 2007; Field et al., 2004b; Jones et al., 2006).

However, few studies have used eye-tracking techniques to assess attentional bias/cue reactivity to alcohol-related scenes. In particular, the alcohol research literature is especially sparse with regard to studies using eye-tracking/ocular-imaging techniques to measure subtle differences in attentional bias to alcohol-related images among social or heavy episodic drinking populations. Eye-tracking techniques are a particularly efficient method of assessing these different components of neurophysiological processing, because eye movements may be recorded on the order of milliseconds in an automatic manner before (and in addition to) more controlled cognitive processing of the visual scene. Although the relationship between attentional bias and drinking characteristics has been firmly established in the literature (Field and Cox, 2008), and attentional bias is known to be measurable using eye-tracking techniques, as demonstrated by Field et al. (2004a) using nicotine-related stimuli, the relationship between drinking characteristics and eye-tracking metrics elicited by acohol-related scenes remains to be addressed more thoroughly. These relationships are elaborated in Figure 1, and the examination of this model is the purpose of the current study.

The current study also provides an initial examination of the automatic and controlled processing of alcohol-related stimuli as indexed using eye-tracking metrics. According to the model proposed by Wiers (2007), addictive behavior is regulated by the interaction of three factors. The first factor includes explicit attitudes related to voluntary consumption of a substance. The second factor consists of implicit preferences for and automatic appetitive responses to a substance. The third factor involves the ability to inhibit automatic appetitive responses and motivations to use a substance. Addictive behaviors such as excessive alcohol consumption may develop as the result of an imbalance in this system, which becomes sensitized with repeated exposure to an addictive substance. Thus, the model of Wiers et al. (2007) is conceptually related to the incentive-sensitization theories espoused by Robinson and Berridge (1993). This model is particularly applicable to the current study, because it accounts for not only the explicit attitudes/beliefs about alcohol that are often experienced during college but it also addresses automatic/implicit responses to alcohol-related images below the level of conscious recognition. In addition, the current study used the model of Wiers et al. (2007) to extend the literature beyond traditional pencil-and-paper behavioral assessments to measure the more automatic and physiological correlates of alcohol-related attitudes and beliefs.

To obtain meaningful information from eye movements elicited by stimuli presented on a computer screen, movement recordings are typically processed to extract basic eye movement types such as fixations, saccades, and pursuits. Fixation is defined as an eye movement that keeps an eye gaze stable with regard to a stationary target, providing visual images with the highest level of acuity (Duchowski, 2007). Saccades are very rapid eye rotations that move the

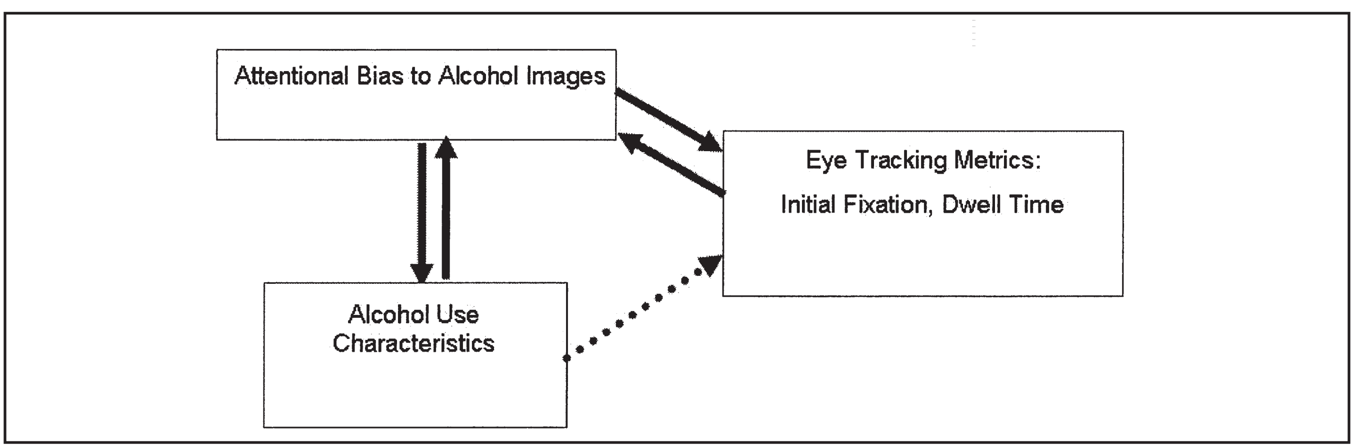

FIGURE 1. Relationships of attentional bias, eye-tracking metrics, and drinking characteristics. The relationship between drinking characteristics and attentional bias (see Field and Cox, 2008) and attentional bias and eye-tracking metrics (see Field et al., 2004) have been previously established. The current study focuses on elucidating the relationship between drinking characteristics and eye-tracking metrics to alcohol-related stimuli.

eye from one fixation point to another, and pursuit movements act to stabilize the retina with regard to a moving object of interest (Duchowski, 2007). It is important to outline the exact algorithm used to detect each eye movement type, as different parameterizations of one algorithm might lead to various results (Komogortsev and Khan, 2008). In case of stationary pictorial stimuli, images are static; therefore, there is no pursuit movement. A picture of the highest acuity is captured by the brain during fixations; therefore, fixation-based metrics are used as the main tools of evaluation in studies using visual cues (Field et al., 2004a; Mason et al., 2005).

To study both automatic and controlled processing of visual scenes, the dependent variables of the current study included dwell time, which is defined as the sum of eye fixation durations recorded for the alcohol-related or control stimuli. This measure indicates the amount of cognitive load experienced by the participant while performing the task and represents an index of "controlled" processing. Another variable of interest was the initial fixation analysis or the direction of the participants' initial fixation toward alcohol or control stimuli. This metric indicates the initial salience of the selected picture and represents an index of "automatic" processing.

To further examine the relationship between alcohol-consumption characteristics and eye-tracking metrics, pupil diameter in response to alcohol and control images was also included in separate analyses. Pupil diameter was recorded during fixations in response to alcohol-related and non-alcohol-related stimuli. Larger pupil diameter is indicative of the larger cognitive effort expended during perception (Poole and Ball, 2006). In summary, the current study examined college students' attention to alcohol-related beverages in real time using ocular-imaging techniques. The authors hypothesized that current alcohol consumption characteristics such as the quantity-frequency index (QFI) would predict ocular-imaging indices of attentional bias to alcohol-related images.

Method

Participants

Thirty-six college students were recruited via opportunity sampling, as well as announcements in undergraduate courses at Texas State University. Participants were compensated for their participation with extra credit in courses within the Departments of Psychology or Computer Science. All materials and procedures were approved by the Institutional Review Board at Texas State University, and informed consent was obtained from all participants before the testing session.

Recruitment materials referred to the study as an image based eye-tracking experiment and made no mention of the alcohol-related aspects of the task. All participants completed the questionnaire materials (described later) as part of a "background assessment" that occurred after their completion of the eye-tracking task. At no time during their experimental session were the participants informed of the true purpose of the study; that is, to examine the relationship between eye-tracking responses and their quantity-frequency of alcohol consumption.

Questionnaires

In addition to basic demographic information and history of alcohol use, participants completed an index of alcohol consumption (the QFI) over the previous 6-month period (Cahalan et al., 1969).

Attentional bias paradigm

The current study used an alcohol-related adaptation of a paradigm originally designed to measure attentional bias to tobacco-related images (Field et al., 2004a). An example of the paradigm is depicted in Figure 2. The pictorial stimuli used in the alcohol-related attentional bias task consisted of 20 digital color photographs of alcohol-related scenes (e.g., individuals consuming alcohol or pouring alcohol, and/or pictures of individual servings of wine, beer, or distilled spirits). Each photograph was presented with a pair depicting another scene (control) matched as closely as possible for content but lacking any alcohol-related cues. Twenty pictures of household items and individuals interacting with household items were used as the control condition. Pictures presented in the paradigm included proprietary images developed in the Health Psychophysiology Laboratory at Texas State University.

Participants were instructed to fixate on the center of the screen and were presented with a fixation image (e.g., the cross-hair cursor), which was displayed for 1,000 ms. After 1,000 ms, the fixation image was replaced by two pictures: one with alcohol-related cues (e.g., a hand holding a mixed drink) and one without alcohol-related cues (e.g,. a hand holding a telephone). These images were presented side by side for a duration of 2,000 ms. Images were balanced as to the left- or right-side presentation of alcohol-related stimuli. Side-by-side images of ordinary household objects (e.g., a box of tissues, a coffee canister) were interspersed randomly between the alcohol-related trials. Further, the frequency of images—in cluding objects, full face, or partial body (e.g., hand or arm)—were balanced across trials and equated with regard to gender and race/ethnicity. As per Field et al. (2004a), alcohol-related and control pictures were 95 mm high × 130 mm wide when displayed on the computer screen, and the visual angle between the fixation position and the inner edge of each picture was 1°.

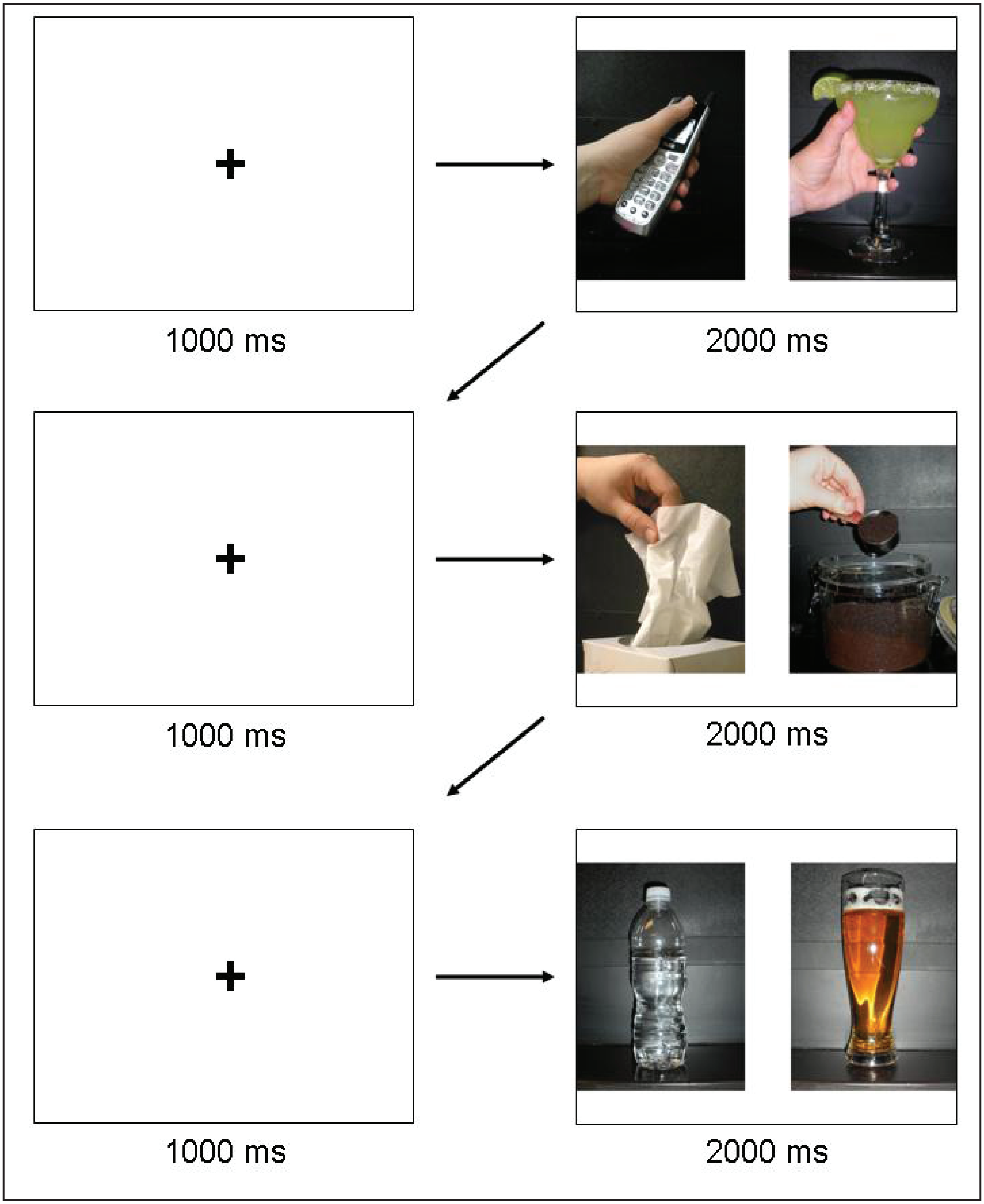

Figure 2. Alcohol-related eye-tracking task: example of timing characteristics. Participants were presented with pictorial stimuli consisting of photographs of alcohol-related scenes, household objects, or a combination of these items. Eye movements were tracked continuously throughout the task.

After focusing on the fixation dot, participants were then presented with the test images (e.g., two pictures presented side-by-side on the computer screen). Before initiating the task, participants were instructed to freely view the test images.

Ocular-imaging methodology

Eye tracker–based metrics were evaluated with the Tobii ×120 eye tracker (Stockholm, Sweden) with the following characteristics: sampling rate of 120 Hz, accuracy (difference between the recorded and actual eye position) of 0.5°, spatial resolution of 0.2°, and drift of 0.3°. The Tobii ×120 eye tracker is noninvasive and allows for 30 × 22 × 30 cm freedom of head movement. Initial eye position data were recorded by Tobii Studio software. The analyses of initial fixation location, average dwell time and pupil diameter were created using MATLAB software (The Mathworks, Inc., Natick, MA; additional information is available from the co-author, Dr. Komogortsev).

Quality of the recorded data

Before the experiment, participants were screened for the actual accuracy and noise levels of the eye-tracker hardware using software developed in the Human Computer Interaction Laboratory in Texas State University. Participants with reported accuracy of less than 1° and a noise level of more than 16% were excluded from analysis of eye movement data. The noise level is defined as the percentage of eye position samples for which the eye tracker failed to report the eye position coordinates. Some of the recording failure of the eye tracker equipment occurred as a result of conditions such as squinting and excessive moisture of the eye. In eye-tracking experiments, such noise-level parameters are rarely reported, but it serves as a major validation metric that should be specifically stated to verify the validity of the results.

Thirty-six participants completed the study. Ten participants were excluded on the basis of poor quality of recorded data (e.g., the parameters previously described). Thus, 26 participants (22 men) were used in the statistical analyses for the article.

Saccade and fixation detection algorithm

The detection algorithm used in the current study is based on the Velocity-Threshold Identification model (Salvucci and Goldberg, 2000). This model detects basic eye movement types based on the dynamics of eye globe rotation and thus has more synergy with oculomotor mechanics (Komogortsev and Khan, 2009). An eye position sample is classified as belonging to a saccade if the calculated eye velocity exceeds 30°/s and if fixation of the eye velocity falls below this threshold. The threshold value of 30°/s is suggested by the oculomotor research literature (see Leigh and Zee, 2006). Saccades with such parameters as onset, offset, amplitude, and duration were detected as a result of merging a sequence of continuous eye position samples with calculated velocity exceeding 30°/s. Saccade amplitude was measured as a Euclidean distance between the coordinates of the first and last point in that sequence and was represented with degrees of visual angle. Saccades with amplitudes of less than 2° and saccades in which the eye tracker failed to detect an eye position, even for a single sample, were discarded from analyses. A fixation was defined as a sequence of eye position samples with velocity of less than 30°/s and occurring not more than 2° apart. Sequences of eye-tracking failures or blinks of less than 75 ms were considered as a part of the fixation duration. Minimum fixation duration was defined as 100 ms. Fixation location was defined as a centroid created by all valid eye-position coordinates excluding micro saccades (saccades with amplitude of less than 1°). Eye fixation duration was defined as the time difference between the last and first samples in the fixation sequence.

Dependent variables for statistical analyses included dwell time, defined as the sum of eye fixation durations recorded for the alcohol-related or control stimuli. Initial fixation, or analysis of the direction of the participants' first fixation toward alcohol or control stimuli, was also analyzed. Although the eye-tracking task employed in the current study required only passive viewing of the material, dwell time reflected the cumulative investigation of alcohol versus control images, which was used as an index of the cognitive load experienced by participants while viewing a particular scene. Finally, pupil diameter in response to alcohol and control images was included in separate analyses. Pupil diameter was recorded during fixations in response to alcohol-related and non-alcohol-related stimuli.

Data analysis

Demographic information resulting in continuous variables was summarized using means and standard deviations; results are shown in Table 1. In the eye-tracking analyses of interest, separate correlational analyses were conducted to determine the utility of the QFI and other alcohol-related and demographic variables in the prediction of eye-tracking metrics. Partial correlations were used to examine the relationships between alcohol-related measures and eye-tracking metrics while controlling for the effects of age.

Results

Demographic and background information

Participants were a mean (SD) age of 20.62 (2) years (range: 18-25). Of the 26 participants tested, 85% were

Table 1. Demographic characteristics of study participants ($N = 26$)

Variable	Mean (SD) or %
Age	20.6 (2.0)
Male	85%
White	69%
Total quantity-frequency index	0.45 (0.61)
Age at first drink	14.14 (4.39)
Days since last drink	6.69 (9.44)

male, and 69% were white. The average quantity-frequency of alcohol consumption for the sample was 0.45 (0.6), which equals approximately one drink or less per day (Cahalan et al., 1969). The range of drinking styles varied from a reported QFI of 0.00 (i.e., participants who do not consume alcohol in any regular pattern) to a QFI of 1.96, which equals approximately three drinks on an average day. The average age at first drink was 14 (4) years (range: 5-20). The number of days since participants' last drink of alcohol at the time of testing was an average of 7 (9) days (range: 2-40).

Dwell time

Quantity-frequency of alcohol consumption positively predicted participants' dwell time on alcohol-related images (r =.57, 23 df, p = .005), and negatively predicted dwell time on control images (r = -.41, 23 df, p = .05). No significant relationship was noted between age at first alcohol consumption (r's < |-.11|, 22 df, p's > .63) or time since last alcohol consumption (r's < |-.24|, 16 df, p's > .38] and dwell time on alcohol and control images. As age was significantly positively correlated with quantity-frequency of alcohol consumption in the current study (r = .43, 23 df, p = .04), a second set of correlational analyses was conducted with age included as a control variable. Results indicated a significant positive correlation between quantity-frequency of alcohol consumption and dwell time on alcohol-related images (r =.53, 20 df, p = .01) and a significant negative correlation between QFI and dwell time on control images (r = -.44, 20 df, p = .04). Results for age at first alcohol consumption (r's < .18, 11 df, p's > .57) and time since last alcohol use (r's < |-.19|, 13 df, p's > .50] remained nonsignificant when the effects of age were controlled.

Initial ocular fixation

Quantity-frequency of alcohol consumption was positively related to the percentage of initial ocular fixations on the alcohol-related items (r = .62, 23 df, p = .001), whereas QFI negatively predicted the percentage of initial ocular fixations on the control images (r = -.60, 23 df, p = .002). Measures of age at first drink (r's < |-.10|, 22 df, p's > .64) and time since last alcohol consumption (r's < .23, 16 df, p's > .39) were not significantly related to eye-tracking metrics. Because age was significantly positively correlated with quantity-frequency of alcohol consumption in the current study (r = .43, 23 df, p = .04), a second set of correlational analyses was conducted with age included as a control variable. Results indicated that QFI remained significantly positively related to the percentage of initial ocular fixations on alcohol-related images (r = .58, 20 df, p = .004) and signficantly negatively related to the percentage of initial ocular fixations on control images (r = -.57, 20 df, p = .006). Age at first drink (r's < .043, 11 df, p's > .89) and time since last alcohol consumption (r's < .20, 13 df, p's > .48) were not significantly related to the eye-tracking metrics (r's < .18, p's > .48).

Pupil diameter

Age at first drink (r's < .01, 22 df, p's > .98), days since last alcohol use (r's < .22, 16 df, p's > .42), quantity-frequency of alcohol use (r's < .04, 23 df, p's > .87), and age (r's < .23, 26 df, p's > .26) were not related to pupil diameter during fixation on alcohol- or control-related stimuli.

Discussion

Attentional bias to alcohol-related images is an important tool to increase the understanding of cognitive processes underlying alcohol misuse among college students. The current study is unique in that attentional bias measures were obtained using ocular-imaging methodology, allowing for assessment of both "automatic" (e.g., scene salience, reflected in the point of initial fixation) and "controlled" (e.g., cumulative dwell time during the 2,000 ms presentation of the images) processing of alcohol-related stimuli. Results indicate that quantity and frequency of alcohol consumption among college students is positively related to both the amount of time that students spend viewing alcohol-related images (vs control scenes) and the frequency with which they are attracted to the alcohol-related scene on first viewing the scene sets (e.g., salience). These results suggest that reactions to alcohol-related stimuli among college students have both a significant automatic component, that occurs on the order of milliseconds, and a significant controlled processing component, that may be tracked over the course of the presentation of an alcohol-related scene.

However, although our experiment addressed issues of criterion validity for the variables of dwell time and initial fixation as indicators of alcohol-related attentional bias, an empirical test of these variables as separate indices of automatic and controlled processing was beyond the scope of the current study. From a theoretical perspective, the characteristics of the respective variables are consistent with automatic versus controlled processing. However, because the results for these two measures were quite similar, the analyses of the current study do not demonstrate discriminant validity of these metrics as indices of automatic versus controlled cognitive processes. It is likely that automatic and controlled cognition, as measured using eye-tracking methodology, may have meaningful differential associations with other relevant constructs such as implicit associations or drinking expectancies/motives, respectively. Additional work is needed to examine the nature of these potential relationships.

Although the use of eye-tracking techniques to address the theoretical issues of Wiers et al. (2007) is innovative, the current study has a number of limitations that are currently being addressed in our laboratory. For instance, the current study used a relatively small sample of college students who were predominantly male and of European-American descent. This small *N* could have contributed to the lack of significant findings with regard to a variety of alcohol-related characteristics (e.g., age at first drink, days since last drink—variables for which missing data points were prevalent) as well as measures of pupil diameter. However, other research suggests that the reliability of pupil-related metrics may be less significant than for other types of ocular measures (Yoon et al., 2007). Further, given the cultural differences in attitudes and beliefs regarding college drinking (Corbin et al., 2008), future work should focus on a more ethnically diverse sample of male and female participants. In addition, a more extensive examination of psychosocial factors associated with alcohol use on college campuses was beyond the scope of the current investigation.

Finally, additional analyses of ocular responses to complex alcohol-related scenes with movement could provide saccadic and pursuit-related eye-tracking metrics, including saccade latency, saccade hypometria (the amount of overshoot of the fixation target) and hypermetria (the amount of undershoot of the fixation target), saccadic intrusions and oscillations, as well as pursuit gain (Leigh and Zee, 2006). Such experiments could further substantiate the current findings.

Despite these limitations, the current study indicates that eye tracking of real-world visual images is a valid technique for the study the cognitive processing of alcohol-related scenes. Although preliminary, these results contribute to a better understanding of the mechanisms underlying alcohol-related attention and perception in the college environment. These findings could ultimately be applied to the development of attentional training programs (e.g., adaptation of Schoenmakers et al., 2007, and/or Townshend and Duka, 2007) for the treatment and prevention of excessive alcohol consumption on college campuses. This approach is supported by a number of recent studies demonstrating attentional biases in other conditions as well. For instance, depressed populations have been shown to have attentional bias to depressive information, a condition that is considered a vulnerability factor for the development of depression (Erickson et al., 2005; Koster et al., 2005). Chronic pain patients also show cognitive bias toward pain-related information, and these biases may be used to predict the functioning of these patients (Dehghani et al., 2004). Thus, understanding the link between attentional bias across populations may help to identify which key components are necessary for effective interventions.

Conclusion

Ocular-imaging methods are a valuable tool for use in the study of attentional bias to alcohol-related images in social drinking samples. Results indicate both automatic and controlled components of ocular movement may be related to the quantity and frequency of alcohol consumption among college students. Further research is needed to determine the potential application of these methods to the prevention and treatment of alcohol misuse on college campuses.

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