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Measuring Heightened Attention to Alcohol in a Naturalistic Setting: A Validation Study

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Abstract

Attentional bias to alcohol-related stimuli is believed to be an important contributor to the development and maintenance of drug abuse. There is a considerable body of research examining attentional bias, much of which has typically utilized image-display tasks as a means to assess the phenomenon. Little, however, is known about the nature of this bias in an individual's natural environment. The current study sought to implement a novel approach to assessing attentional bias *in vivo*. Participants wore portable eye-tracking glasses that recorded video from their point of view and measured fixation time to objects they observed. They entered a room that was designed to represent a recreational setting where both alcohol and non-alcoholic "neutral" beverages were placed along with other stimuli. In two different testing sessions, participants were free to visually explore the room. Participants showed similar fixation times to alcohol and neutral beverages during session 1. Attentional bias to alcoholic beverages was observed in session 2, as fixation time decreased to neutral and but not to alcoholic beverages. The magnitude of attentional bias was positively associated with drinking habits, with heavier drinkers demonstrating a higher degree of bias to alcohol. These findings provide an ecological model of how attentional bias can develop as the net result of attention being sustained to alcoholic stimuli while diminishing to other stimuli over time.

Keywords

attentional bias; alcohol; in vivo; novelty; habituation

Research has shown that substance users tend to allocate disproportionate attention towards substance-related cues. Such "attentional biases" to drug-related stimuli are considered to play an important role in the development of drug abuse (Goldstein & Volkow, 2011). Incentive-sensitization theory posits that drugs of abuse have the ability to produce neuroadaptations in incentive motivation and reward systems, causing these systems to become hypersensitive to both drugs and drug-related stimuli (Robinson & Berridge, 2001). Through classical conditioning, with repeated use, substance-related cues come to be

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associated with drug consumption and the ensuing incentive-motivational and rewarding effects of the drug, such as an increase in dopamine levels (Ryan, 2002; Franken, 2003). As a result, drug-related stimuli become increasingly salient for users, receiving greater attention and eliciting increased motivation to seek and use the drug.

Considerable research has examined drinkers' attention to alcohol. Studies report alcohol abusers allocate increased attention to alcohol-related cues (for a review, see Field & Cox, 2008). Attentional bias to alcohol is typically assessed by image-display tasks that measure reaction time to images. In the visual dot probe task, the most widely used measure of attentional bias, alcohol-related and neutral stimuli are briefly presented side-by-side on a computer screen. Individuals inspect both images after which a probe stimulus is presented in the location where either the alcohol or the neutral stimulus had been displayed. Reaction time to detect the probe's location is measured and used to assess attentional bias, with shorter detection times for alcohol locations being indicative of attentional bias to alcohol-related stimuli (Posner, Snyder & Davidson, 1980). More recently, eye-tracking tasks have been used to provide a more direct assessment of attention to alcohol-related stimuli in the visual dot probe task (Miller & Fillmore, 2010; Weafer & Fillmore, 2012). Eye-tracking analysis assesses where an individual is looking on a computer screen and the amount of time spent fixated on an image. Attentional bias is indicated by longer fixation times on alcohol-related images compared to the neutral images (Miller & Fillmore, 2010).

Although image-display assessments provide evidence for attentional bias to alcohol-related stimuli, limitations of these assessments have been reported. Some research has noted that tasks such as the visual dot probe have low internal reliability and the ability of such image-display tasks to predict behavior and potential relapse has also been questioned (Ataya et al, 2012; Christiansen, Schoenmakers & Field, 2015). Image-display tasks are also limited to evaluations of attention to pictorial displays of alcohol-related stimuli and not the actual alcohol-related objects as they are encountered in the natural environment. These tasks also restrict the scope of the participants' attentional allocation by requiring them to limit their gaze towards only the two target images (alcohol or neutral) displayed on the screen during a trial. By contrast, in the natural environment, there are no such constraints on the scope of attentional allocation as individuals are free to explore and inspect the rich array of stimuli in their environment, many of which compete for attention. Taken together, it is difficult to make conclusions from image-display studies about how drinkers might allocate attention to actual alcohol-related objects in natural settings outside the laboratory.

Recent advances in eye-tracking technology have led to portable eye-tracking eyewear. Eye-tracking "glasses" can be worn like any form of eyewear (Tobii Technology, Sweden). The glasses are equipped with sensors directed towards the eyes to record pupil movement and a front-facing camera to video record the user's field of view. Pupil movement is continuously mapped onto the video record to determine the user's precise points of ocular fixations and saccades within their field of view. The apparatus is wireless and not attached to any other component, allowing the user complete freedom of head and body movement to navigate and visually explore any environment. Eye-tracking glasses have been used primarily in applied market research to study how shoppers attend to merchandise and advertisements as a function of their location within shopping venues (Tonkin, Ouzts & Duchowski, 2011;

Hurley, Ouzts, Fischer & Gomes, 2013). With regard to alcohol, actual alcohol-related objects (e.g., liquor bottles) can be studied as targets of attentional focus instead of pictorial representations on computer displays. Moreover, attention to these actual objects can be examined *in vivo* as the individual explores and encounters these objects in a naturalistic environment, such as a bar, lounge, or other recreational setting.

Although eye-tracking glasses have the potential to provide a more ecologically-relevant assessment of attentional bias to alcohol, they also pose certain methodological challenges. Allowing individuals to freely inspect and attend to the rich array of visual stimuli in a given setting represents a substantial loss of experimental control over which stimuli are to be attended. Image-display tasks typically restrict the focus of attention to only two stimuli (the alcohol and the control "neutral" image). Eye-tracking glasses, however, allow unrestricted attendance to all stimuli in the environment. Such freedom to visually inspect an environment raises the need to consider how stimuli can capture attention owing to characteristics other than their relevance to alcohol. Chief among these characteristics might be the novelty of the stimuli that are encountered. Individuals allocate significantly more attention to novel compared with familiar stimuli (Fagan & Haiken-Vasen, 1997). A stimulus may be considered novel when it has never been encountered before or if it is being seen in a new context or environment (Duckworth, Bargh, Garica & Chaiken, 2002). With repeated exposure to the stimulus, allocation of attention diminishes (Tipper, Borque, Anderson & Brehaut, 1989). Novelty-driven attentional bias effects are pronounced and can occur regardless of whether or not a stimulus has any inherent appetitive property for the individual. As such, it could be difficult to discern attentional bias to alcohol-related stimuli in a novel environment in which all stimuli elicit a high degree of attendance. However, with repeated exposures to the environment, attention to many stimuli should habituate as they become familiar, so that heightened and consistent attention to those stimuli with incentive properties for the viewer, such as alcohol-related objects, might be better observed over time.

The current study used the eye tracking glasses in an *in vivo* assessment of attentional bias to alcoholic beverages with a group of young adult alcohol drinkers. Participants entered a recreational room containing several objects, including non-alcoholic and alcoholic beverages. They were allowed to freely visually inspect all objects. Effects of novelty and alcohol-relevance of the objects were examined by assessing participants' attentional bias over the course of repeated exposure to the room. We hypothesized that attentional bias to alcoholic beverages would be observed and that this effect would be most evident after participants became familiar with the environment (i.e., after re-exposure to the room). The current study also tested the hypothesis that the degree of attentional bias to alcoholic beverages would be directly related to the participants' drinking habits, with greater attentional bias being displayed by the heaviest drinkers.

Methods

Participants

Thirty-five adults (16 men and 19 women) between the ages of 21 and 33 years participated in this study (mean age = 24.6, SD = 3.4). The racial make-up was as follows: American

Indian (n = 1), African American (n = 5), Latino/Hispanic (n = 3) and Caucasian (n = 26). 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 drinking frequency of at least once per week over the past 90 days, and no history of alcohol use disorder or treatment for alcohol use. Participants were also excluded if they reported any eye or vision issues that would interfere with the eye-tracking glasses' ability to track their eyes. Individuals with corrected vision were required to use contact lenses so that they would be able to wear the eye-tracking glasses.

Materials and Measures

Eye-tracking glasses—Attentional bias to real world objects was measured using Tobii Pro Glasses 2 (Tobii Technology, Sweden). Individuals were placed in a laboratory room with the eye-tracking glasses recording eye movements and video using Tobii Pro Glasses Controller on a tablet PC. Eye locations were sampled at 60 Hz and were mapped onto video recordings from the wearers' perspective. Video recordings were analyzed for fixations using Tobii Glasses Analysis Software, which generated a video frame every 20 ms. Fixations were defined as gazes where there was no eye movement for a duration 50 ms or longer. For frames where a fixation occurred, the location of the fixation fell into one of three locations: alcohol beverages, neutral beverages, or non-beverage locations. Alcohol and neutral beverages were matched for number, size, shape and complexity. The total duration of all fixations directed towards each type of beverage (i.e., alcohol and neutral) was averaged across exposures to produce a mean fixation time for each beverage. The glasses are completely portable, connected via a cable to a small battery pack the wearer can clip to themselves, fit in their pocket or carry. This battery pack stores the video recording from the front-facing camera embedded into the glasses as well as stores all eye-tracking data. It also communicates wirelessly with a tablet PC that allows for live observation from the wearer's perspective of both the video recording and eye movements mapped onto the video.

Timeline Follow-Back (TLFB)—Participants drinking habits were assessed using the timeline follow-back procedure (Sobell & Sobell, 1992), which assessed daily drinking patterns over the past 3 months. Participants were asked to fill in a blank calendar dating back 90 days from the testing session. For each day, individuals were instructed to report how many standard alcohol drinks they consumed, the duration of their drinking episode, and whether or not they felt drunk that day. From this information, four measures of drinking habits were obtained: (1) total number of drinking days (drinking days), (2) total number of drinks consumed (total drinks), (3) total number of days characterized by subjective drunkenness (drunk days), and (4) total number of days in which binge drinking occurred (binge days). Binge drinking days were determined by estimating participants BACs on each day according to the reported number of drinks they consumed as well as the amount of time they spent drinking using anthropometric-based BAC estimation formulae that assume an average clearance rate of 15 mg/100 ml per hour (Watson et al., 1981).

Alcohol Use Disorders Identification Test (AUDIT)—The AUDIT is a screening instrument that is used to identify at-risk problem drinkers (AUDIT; Saunders et al., 1993). It was used in the current study to provide a brief assessment of problematic alcohol use. The 10-item self-report questionnaire consists of 10 items about drinking patterns, negative psychosocial outcomes, and other indicators of alcohol use disorder. Scores on this measure can range from 0 (no alcohol-related problems) to 40 (severe alcohol-related problems).

Procedure

The study took place over the course of two test sessions at the Behavioral Pharmacology lab in the Psychology Department. This study received research ethics committee approval from the University of Kentucky Institutional Review Board under protocol number 12-0737-FIV entitled *Behavioral Dysregulation and Alcohol Sensitivity in Risky Drivers.* During the first session, informed consent was obtained, followed by completion of questionnaires on demographics, general health status, drug use, and the TLFB and AUDIT. A zero BAC was verified by a breath analysis. Participants were then acquainted with the eye-tracking glasses. It was explained that the purpose of the study was to test the glasses as a new piece of equipment for visual research. Participants were instructed on the basic functions of the glasses, including that the glasses recorded their field of view and could monitor their pupils at the same time. Participants were instructed to enter and visually explore a recreation room while wearing the eye-tracking glasses for an unspecified period of time. They were told that they were free to walk about the room and to look at whatever they wished. So as to avoid possible bias of their attention we provided no explicit information about assessing their attention to target objects in the room. The room contained posters, tables, a refrigerator, a television, chairs, a dart board and various other bar-like and recreational setting, non-target stimuli. In addition, eight target objects were distributed throughout the room: four alcohol beverages and four neutral, non-alcohol beverages. Target objects were divided into four pairs, where each pair consisted of one bottle of alcohol varying in size and type of alcohol (i.e., beer or rum) and a bottle of a non-alcoholic beverage (i.e., tea or soda). Objects paired together were matched based on size, color of liquid and the complexity and color of their labels. Each object in the pair was placed beside one another at the same location and height so that they were equally visible and spaced no more than two feet apart from one another.

The viewing session was observed remotely by the experimenter on a tablet PC that wirelessly communicated with the eye-tracking glasses. This remote viewing provided the experimenter with a real time video of the exposure from the point of view of the participant. The video also provided a real-time indicator of the specific eye movements to, and fixations on, the alcohol and neutral objects. A test was comprised of five one-minute exposures, each separated by a five-minute break. One minute exposures prevented boredom and kept video data file size to a manageable size for analyses. During breaks, participants were escorted to another laboratory room where they relaxed and read magazines which contained no alcohol-related content.

Participants' attended a second test session to determine if attentional bias to alcoholic beverages is stronger after individuals have been exposed to the room for one session. As in

session 1, participants provided a breath sample to verify a zero BAC. They then completed the *in vivo* assessment of attentional bias as it was conducted in session 1. The inter-session interval ranged from three days to two weeks. At the conclusion of the second testing session participants were paid and debriefed.

Criterion Variables and Data Analyses

Attentional bias to alcohol-related objects was assessed. The eye-tracking glasses provided the fixation time spent on objects in the room during each one-minute exposure. Longer fixation times spent on an object was indicative of increased attention paid to that stimulus. For each exposure, fixation times were totaled across the four alcohol objects and totaled across the four neutral objects. These totals were then averaged across the five exposures for a testing session to provide a mean fixation time for alcohol and for neutral objects per exposure. Greater fixation times to alcohol versus neutral object indicated attentional bias to alcohol. Fixation times were analyzed by a 2 (session) X 2 (stimuli; alcohol, neutral) repeated measures analysis of variance (ANOVA). Additionally, for each session, a 2 (stimuli; alcohol, neutral) X 5 (exposures) ANOVA analyzed fixation times across the five individual exposures to determine if there was any change in attentional bias within the session.

The relationship between attentional bias to alcohol-related objects and drinking habits obtained from the TLFB was examined via correlational analyses. Analyses were all conducted to include sex as a between-subjects variable. These analyses found no significant effect of sex and did not change the significance level of other main effects or interactions. As such, reported analyses of attentional bias and other measures are collapsed across sex.

Results

Drinking and Demographic Information

Participants' drinking habits and demographic information are presented in Table 1. Drinking habits showed that participants were regular drinkers and comparable to those who have demonstrated attentional bias in previous studies (Miller & Fillmore, 2010; Roberts, Fillmore & Milich, 2012). In addition to moderate alcohol use, some participants reported past month use of nicotine (n = 8), marijuana (n = 6), and sedatives (n = 2). Participants verbally confirmed abstinence from substance use during the 24 hours prior to each session, and breath analysis confirmed a zero BAC.

Fixation Times

Fixation times are plotted in Figure 1. As the figure illustrates, the total fixation time spent on target objects per one-minute exposure was approximately 16 to 18 seconds, representing 25–30% of total exposure time. The 2 (stimuli) x 2 (session) ANOVA of fixation time revealed a significant stimuli x session interaction, $F(1, 34) = 6.071$, $p = .019$. Figure 1 illustrates the nature of this interaction. In accord with the hypothesis, the difference in fixation time between alcohol-related versus neutral objects was greater during session 2 compared with session 1. Thus, as predicted, attentional bias to alcohol was greatest during later exposures. Simple effects analyses showed that, in session 1, the difference between

alcohol and neutral fixation times was not significant, $t(34) = -0.309$, $p = .76$. In session 2, however, attentional bias was observed as fixation time to alcohol stimuli was greater than to neutral stimuli, $t(34) = 2.903$, $p = .006$. This interaction appeared to be largely due to a significant decline in fixation time to neutral objects from the session 1 to session 2, $t(34) = 2.131$, $p = .04$. No such decline was found for fixation time to alcohol objects between sessions, $t(34) = -0.645$, $p = .52$.

The possibility that attentional bias to alcohol beverages changed within a session was also examined. The 2 (stimuli) x 5 (exposures) ANOVA of fixation time revealed no significant stimuli x exposure interaction in either testing session, $ps > .05$.

Reliability of *in vivo* Attentional Bias

We examined the consistency of individual differences in fixation times across the five one-minute exposures in a session by calculating their internal consistency via Cronbach's alpha. Table 2 presents means, standard deviations, range and Cronbach's alphas for fixation times for each alcohol and neutral targets in each session. Cronbach's alphas were modest in session 1, but were greater in session 2 (> 0.80) indicating more consistency of individual differences in fixation time to target objects during session 2.

Validity of *in vivo* Attentional Bias: Relationship to Drinking Habits

Regression analyses using drinking habit measures as a predictor of attentional bias were examined to determine if participants reporting heavier alcohol consumption would also display greater attentional bias to alcohol beverages. A single attentional bias score was calculated for each participant as the difference in fixation time spent on alcohol and neutral objects for a session. Table 3 reports the results of the regression analyses. In both sessions, participants' attentional bias scores were positively related to their total drinks consumed and number of binge days in the past 90 days, $ps < .05$. Figure 2 illustrates the positive relationship between total drinks and attentional bias for both sessions where high attentional bias scores were associated with a greater number of drinks consumed in the past 90 days. For number of days of subjective drunkenness in the past 90 days, a positive relationship was found with attentional bias scores in session 2 ($p = .011$) but not session 1 ($p > .05$). Overall, higher attentional bias scores were associated with a greater alcohol consumption.

Discussion

Supporting the primary hypothesis of this study, attentional bias to alcohol beverages in the environment was evident only after participants were re-exposed to the testing room. When comparing fixation times to alcohol and neutral beverages, attentional bias was found during session 2, whereas no such bias was observed in session 1. The study also showed that the reliability with which individuals attended to targets was stronger in session 2 than in session 1. Additionally, this study examined the extent to which participants' drinking habits related to their attentional bias scores. Consistent with the second hypothesis, those who self-reported heavier drinking were shown to have a higher degree of attentional bias than those who reporter drinking less over the past three months.

This study is the first to assess attentional bias with an *in vivo* approach as well as the first to use eye-tracking glasses to achieve such a goal. Our approach allowed individuals to have as much freedom to observe stimuli as they normally would outside of the laboratory. Previous demonstrations of attentional bias to alcohol have been based on highly controlled tests that limit the participant's attention to computer presentations of stimulus images for brief observation intervals (2 secs or less). When the viewer is free to visually inspect an entire environment, many stimuli should initially capture attention based simply on their novelty. We included repeated exposure to the environment to account for the possibility that novelty effects could initially impede the detection of attentional bias to alcohol. Indeed, attentional bias to alcohol beverages was not evident during the initial session. Also, within a session, attention to either alcohol or non-alcohol beverages did not change appreciably over the one-minute exposures. However, as predicted, when re-exposed to the environment during session 2, greater attentional bias to alcohol was observed as attention to the neutral beverages diminished. We also observed greater internal consistency of fixation times during session 2 indicating that allocation of attention to targets stabilized somewhat, possibly a result of participants becoming more familiar and less likely to randomly explore the environment.

Attentional bias was positively associated with drinking habits demonstrating the validity of the *in vivo* method of assessing for attentional bias. Individuals who had more total drinks, binge days and days where they believed they were drunk in the past three months also exhibited a greater degree of attentional bias than those who reported less drinking. These relationships were evident in both testing sessions, but were stronger in session 2, likely due to greater internal consistency of participants' fixation times and a higher overall degree of attentional bias in that session. It is interesting to note that the primary measure of drinking frequency on the TLFB, drinking days, did not predict attentional bias. This could indicate that attentional bias may be a characteristic demonstrated more so by individuals exhibiting patterns of excessive drinking within episode (i.e., binge drinking) rather than frequent drinking. Distinctions between frequency and quantity of drinking are well recognized as typologies of alcohol use disorders, such as Cloninger's Type 1 and Type 2 subtypes (Cloninger, 1987). Type 1 is characterized by excessive quantity during a drinking episode and Type 2 by frequent drinking episodes. The possibility that such *in vivo* demonstrations of attentional bias to alcohol could be more characteristic of a particular pattern of drinking is an interesting and worthwhile consideration for future research, especially in those with alcohol use disorders.

The *in vivo* approach taken in this study to assess attentional bias is meant to emulate an individual's experience encountering alcohol objects in their natural environment. We sought to limit restriction on participants' behavior during the in vivo assessment and placed them in a testing environment more representative of a relaxed, recreational setting rather than traditional laboratory testing rooms. Still, individuals understood that they were participating in an alcohol study and that the study took place in a laboratory. *In vivo* assessments of attentional bias outside of the laboratory could provide more information about the manner in which alcohol stimuli capture attention in situations already familiar to participants, such as their favorite bar. Given the portability of the technology, such studies are now highly feasible. It is also worth noting that the current sample did not consist of individuals meeting

criteria for alcohol use disorder. It is therefore difficult to determine how those either at risk or currently meeting criteria for alcohol use disorders might respond to the *in vivo* assessment of attentional bias and whether it might have any predictive relationship to an individual's success in treatment or predisposition for relapse. To address this, future studies using this in vivo assessment would benefit from using a heavier drinking population.

There are many potential directions for future investigations using this technology to assess attentional bias to alcohol and other drugs in naturalistic, real-world environments. In particular, *in vivo* assessments should be useful in understanding how attentional bias is altered by alcohol or other drug consumption. Studies using computer display tasks to assess attentional bias have shown that the acute administration of alcohol can affect attentional bias (Duka & Townshend, 2004; Weafer & Fillmore, 2013). Eye-tracking technology could build on these findings to evaluate how attentional bias to alcohol changes over the course of one's typical drinking episode in naturalistic setting. Finally, it will be important to compare *in vivo* assessments of attentional bias with those obtained by computer display tasks. Such psychometric-based studies will provide much needed information on the agreement among various approaches to measuring attentional bias to alcohol as a risk factor for alcohol abuse.

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Public Significance Statement

This study found that *in vivo* exposure results in sustained attention to alcohol objects over time with reduced attention to neutral objects over that same period. Attentional bias to alcohol as it is experienced outside of the laboratory may be explained by this difference in habituation to stimuli as opposed to an outright initial preference for alcohol-related stimuli over others, which challenges our current understanding of the nature of attentional bias.

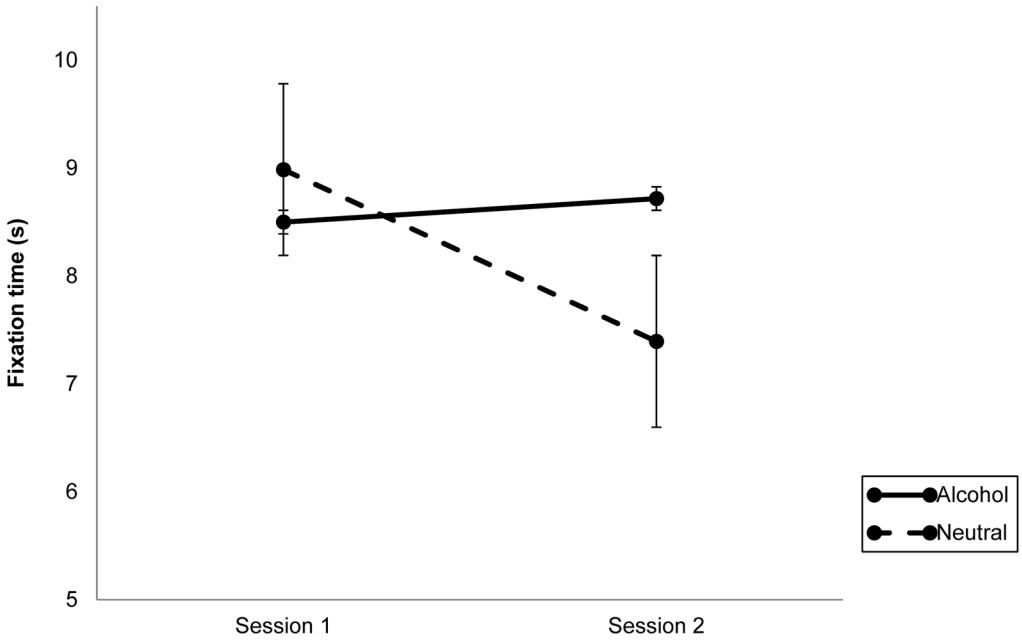

Figure 1.

Average fixation times to alcohol and neutral beverages during the in vivo assessment of attentional bias for both experimental sessions.

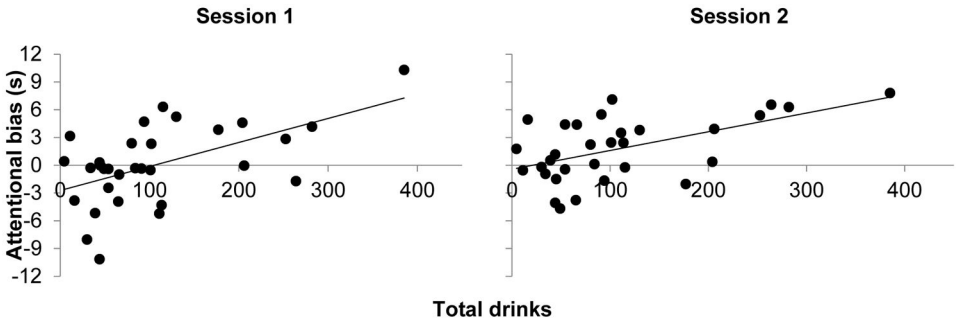

Figure 2.

Relationship between an individual's attentional bias scores and their total drinks over the past 90 days on the TLFB for sessions 1 and 2.

Table 1

Mean Drinking Habits and Demographic Measures by Gender

	Group						Contrasts
	Women			Men			
	M	*SD*	*Min - Max*	*M*	*SD*	*Min - Max*	
Drinking Habits							
TLFB - Binge Days	7.68	10.1	0 – 40	9.88	9.04	0 – 25	
TLFB - Drunk Days	9.79	9.34	0 – 39	10.13	8.61	0 – 27	
TLFB - Drinking Days	24.16	11.04	7 – 47	24.88	12.70	8 – 65	
TLFB - Total Drinks	85.76	74.09	7 – 289	143.81	99.53	39 – 385	
AUDIT	7.105	3.81	1 – 14	10.5	4.351	6 – 21	*
Demographics							
Age	23.89	3.13	21 – 30	26.19	4.23	21 – 34	
Height (cm)	166.18	5.92	157 – 180	175.22	9.17	158 – 189	**
Weight (kg)	66.53	10.65	48 – 90	84.16	14.18	63 – 109	***

Note. Group contrasts were tested by one-way between subjects ANOVAs. Data labeled TLFB is from the Timeline Follow-Back.

* $p < .05$

** $p < .01$

*** $p < .001$

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Table 2

Mean, standard deviation, minimum, maximum and Cronbach alpha of fixation times

	Session 1				Session 2			
	M	***SD***	***Min - Max***	***α***	***M***	***SD***	***Min - Max***	***α***
Alcohol	8.5	3.74	3.4 – 19.3	.61	8.99	7.4	1.7 – 21.9	.83
Neutral	8.72	3.77	3.3 – 18.9	.59	5.21	4.43	1.4 – 22.9	.82

Note. Fixation times calculated as total time per one-minute exposure spent on target objects during in vivo assessment.

Table 3

Regression analyses of attentional bias with Drinking Habits on the TLFB

	Session 1				Session 2			
	b	***t***	***p***	r^2	***b***	***t***	***p***	r^2
Total Drinks	.023	3.34	<.01	.25	.018	3.39	<.01	.26
Binge Days	.180	2.59	.014	.17	.166	3.23	<.01	.24
Drunk Days	.142	1.81	.079	.09	.160	2.71	.011	.18
Drinking Days	.058	0.95	.35	.03	.058	1.22	.23	.04

Note. Drinking habits are self-reported on Timeline Follow-Back as total number in past 90 days. Bias score calculated as difference between fixation time to alcohol and neutral targets.