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ATTENTIONAL BIAS TO ALCOHOL IN AN IN VIVO SETTING

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ATTENTIONAL BIAS TO ALCOHOL IN AN IN VIVO SETTING

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Arts and Sciences at the University of Kentucky

By

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2018

ABSTRACT OF DISSERTATION

ATTENTIONAL BIAS TO ALCOHOL IN AN IN VIVO SETTING

The phenomenon of attentional bias to alcohol, where drinkers demonstrate a preference in allocating visual attention towards alcohol-related stimuli rather than neutral stimuli, is well-established. Studies detecting this phenomenon typically utilize computer-administered stimulus presentation tasks such as the visual dot probe task. Despite their frequency of use, these tasks do not represent the ways in which individuals typically encounter alcohol outside of the laboratory. Typical environments where alcohol is present allow individuals to move about freely and encounter alcohol while also being exposed to many other stimuli. This dissertation sought to implement a novel approach to assessing attentional bias *in vivo*, and identify how alcohol consumption might influence such *in vivo* attentional bias. This two-study dissertation utilized an *in vivo* task where participants looked freely around a room representing a recreational setting containing numerous objects while portable eye-tracking glasses monitored what an individual looked at and for how long. Target items of alcohol and neutral beverages were placed throughout the environment and fixation time spent on these objects was recorded. The first study of this dissertation examined attentional bias to alcohol-related objects across two identical testing sessions to understand the impact of novelty on allocation of *in vivo* attention. The second study tested individuals using the same *in vivo* assessment following a 0.30 g/kg dose of alcohol, a 0.65 g/kg dose of alcohol and a placebo. Participants also completed the visual dot probe task in order to measure and compare their attentional bias in a more traditionally implemented task to the novel *in vivo* approach. Results from the first study indicate that as the novelty of stimuli begins to wane and habituation to neutral stimuli occurs, attentional bias to alcohol-related objects emerges. This attentional bias was shown to be related to drinking habits, where heavier drinkers demonstrated increased attentional bias. The second study in this research found no discernible effect of alcohol consumption on *in vivo* attentional bias, but did identify a satiating effect of consumption on bias as measured by the visual dot probe task. Additional visual dot probe findings suggest the specificity of the effect of alcohol consumption on attentional bias. Together, these findings help inform whether there is benefit in utilizing an ecological model of measuring attentional bias and how the phenomenon might be measured in laboratory settings in the future.

Key words: Attentional Bias, In Vivo, Eye-tracking, Habituation, Satiation, Alcohol

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ATTENTIONAL BIAS TO ALCOHOL IN AN IN VIVO SETTING

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Epidemiological studies show that, in the United States, nearly half of college age students and young adults reported heavy and binge drinking (Marczinski, Grant, & Grant, 2009). According to the NIAAA, 26.9 percent of individuals ages 18 or older reported engaging in binge drinking in the past month and roughly 7 percent of adults reported engaging in heavy alcohol use in the past month (USDHHS, 2004). Damaging behaviors such as assault, unsafe sexual activity, and motor vehicle accidents have all been shown to be linked with heavy alcohol consumption (Flowers et al., 2008; Presley & Pimentel, 2006; Wechsler & Nelson, 2001). For this reason, there has been considerable focus in research towards attempting to understand what is uniquely characteristic of individuals that engage in heavy and binge drinking. Historically, this line of research has primarily investigated factors such as personality traits or genes, both of which have been shown to be linked to a vulnerability for alcohol abuse (Dick & Bierut, 2006; Sher, Grekin, & Williams, 2005).

A more concerted effort has emerged in recent research to shift focus on behavioral and cognitive characteristics which may be linked with heavy alcohol use. Behaviorally, there is evidence that, compared to those who drink less, binge and heavy drinkers demonstrate increased liking and stimulation to alcohol and are more disinhibited by the effects of alcohol consumption (Fillmore, 2003; Fillmore, 2007; Marczinski, Combs, & Fillmore, 2007; Quinn & Fromme, 2011; Weafer & Fillmore, 2008). At the cognitive level, there have been several studies which show that heavy drinkers demonstrate an increased allocation of attention to alcohol-related stimuli compared with lighter drinkers (Miller & Fillmore, 2010; Townshend & Duka, 2001; Weafer & Fillmore, 2013). This increased allocation of attention, known as attentional

bias, is believed to play an important role in alcohol consumption and in identifying those at risk for heavy drinking.

Attentional Bias

Attentional bias is believed to be the result of conditioning in heavy drinkers due to their history of consumption (Field & Cox, 2008). Associations with alcohol use occur alongside the presence of alcohol-related cues, including the alcohol itself, which make these cues more relevant to heavy drinkers than to others. The rewarding experiences and effects of alcohol consumption, along with the desire to drink, becomes linked to the presence of these cues. This is likely the reason that alcohol abusers pay more attention to alcohol-related stimuli over those who do not drink or are not heavy drinkers (Marczinski et al., 2007).

Substance-related stimuli, or cues, elicit classically conditioned responses in substance abusers according to the incentive motivation model (Franken, 2003). Responses that are experienced may be subjective or physiological. For instance, in a heavy user, seeing a substance-related object may elicit craving and increased motivation to use that substance (Ryan, 2002a). This likely occurs due to frequent pairings of substance-related cues with substance administration which, over time, cause these cues become associated with the act of and the experiences a user may have following consumption (Robinson & Berridge, 1993). Substance-related stimuli therefore become increasingly salient to substance abusers. Due to both this increased salience and the associated rewarding effects with such stimuli, those individuals attend to these types of cues much more than non-abusers. Ultimately, increased attention allocated towards alcohol-related stimuli indicates that individuals are more likely to be preoccupied

thinking about alcohol, which is then likely to result in craving for the substance, increasing the probability of consumption.

Although it is believed that attentional bias to substance-related cues may elicit subjective craving, it is possible that experiences of craving may increase an individual's attentional bias (Field & Cox, 2008). As a substance user experiences increased cravings to consume, substance-related cues become more salient and the individual attends to these stimuli more intently. As more attention is allocated to these stimuli over time, the substance-user may experience an even greater desire to consume the drug. This increased desire may then result in increased attentional bias towards that drug, creating a reciprocal relationship between attention and desire to use.

Importance of Attentional Bias

Attentional bias has been the focus of several lines of research in the field of alcohol abuse. It is worth noting, however, exactly why understanding and identifying this bias is important. As previously mentioned, attentional bias to alcohol is likely to develop in heavy drinkers due to classical conditioning. This bias, then, could be considered a cognitive indicator of heavy drinkers and potential alcohol abuse. If an individual has an attentional bias to alcohol, it is possible that they are at a greater risk than others to develop or perhaps already have a substance use disorder. Beyond this, attention allocated to alcohol has been shown to be related to craving (Field & Cox, 2008). This likely indicates that attentional bias may actually serve a role in motivating alcohol consumption.

Alcohol-related stimuli have been theorized to activate an automatic process that elicits an individual to begin consumption regardless of whether that was their intention

(Stacy & Wiers, 2010). Indeed, this motivation to drink driven by a process such as attentional bias can be so powerful it might even overcome active efforts to avoid alcohol use. From this perspective, attentional bias works as a powerful contributor to the initiation of alcohol consumption. Because of this potential consequence of attentional bias, the process has been identified as a target for research considering how to clinically approach alcohol abuse.

Attentional bias may have important implications regarding treatment outcomes and potential treatment for alcohol use. In fact, in one study, individuals who have failed to respond to alcohol use treatment demonstrated higher levels of attentional bias compared to those for who the treatment was successful (Cox, Hogan, Kristian & Race, 2002). This suggests that individuals who may be more resistant to treatment, potentially because of the severity of their alcohol use history, can be identified by the degree of bias towards alcohol-related cues they demonstrate. Indeed, some interventions have identified attentional bias as an area of focus with the intent to reduce the attention-preference to alcohol in those with a history of alcohol abuse (Schoenmakers et al., 2010). Taken together, attentional bias is an important area of focus to provide continued understanding of both what contributes to continued alcohol consumption and potential difficulties some substance abusers may face in recovery. Attentional bias to alcohol could be conceptualized as either a cognitive indicator of alcohol abuse or a potential risk factor for alcohol abuse, or possibly both at once.

Attentional Bias and Alcohol Administration

Despite the wealth of research available on attentional bias, relatively little is known about the impact that alcohol consumption has on the process. With an increased

interest in how the acute effects of alcohol may influence binge drinking, there has also been interest in how attentional bias may be affected. Weafer and Fillmore (2013) demonstrated that a 0.65 g/kg dose of alcohol, targeting a 80 mg/100 ml BAC, resulted in decreased attentional bias compared to placebo. This was considered to be likely due to a reduction in the salience of incentive-motivational properties of alcohol-related stimuli compared to the sober state because the rewarding effects of the active drug were being experienced as opposed to anticipated. Put differently, individuals may have been satiated by alcohol consumption such that the appetitive nature of the cues diminished.

There is some evidence, however, that certain doses of alcohol might actually prime desire for more of the substance. In one study, all subjects exhibited an attentional bias towards the alcohol-related over neutral stimuli, but found that attentional bias was greatest at a dose of 0.30 g/kg of alcohol compared to bias found at either placebo or 0.60 g/kg (Duka & Townshend, 2004). Consistent with findings from Weafer and Fillmore (2013), however, the same study yielded a negative correlation between the attentional bias under the 0.60 g/kg dose and drinking habits such that heavier drinkers demonstrated less attentional bias after alcohol consumption. Another study found that following consumption of 0.30 g/kg alcohol there was an increase in attentional bias in heavy drinkers (Schoenmakers, Wiers & Field, 2008). Overall, it appears that the degree of attentional bias found after consumption of alcohol may vary depending on the amount of alcohol that was consumed.

Measuring Attentional Bias

Attentional bias has been studied using a variety of methods, often relying on performance or reaction time measures to determine if an individual has an attentional

bias to alcohol. One such task used frequently is the visual dot probe task (Field & Cox, 2008). In this task both alcohol-related and neutral stimuli are presented simultaneously on a computer screen. Individuals are asked to look at both images before they disappear and a target is presented in place of one of the images to which the participant then responds. Reaction times to probes that replaced both alcohol-related and neutral stimuli are compared to one another. Faster reaction times to probes that replace alcohol-related stimuli than those replacing neutral stimuli are considered indications of attentional bias. This is believed to capture attentional bias because individuals tend to respond more quickly to probes that appear in areas that are already being given attention (Posner, Snyder & Davidson, 1980).

Another task that has seen frequent use to measure attentional bias is the addiction-Stroop task (Ryan, 2002b; Cox, Fadardi & Pothos, 2006). The addiction-Stroop task is a modified version of the classic Stroop test (Stroop, 1935). Using addiction related words, performance interference is determined by calculating the difference between participants' performance when presented with substance-related words and their performance to neutral words. This task demonstrates how performance suffers due to a participant's being distracted by a stimulus that that they are instructed to ignore during the task. A greater impairment in performance following the substance-related words compared to their performance in the task with neutral words is considered to be an indicator of attentional bias.

A more recent, but less often used, task that has been utilized to identify attentional bias is the flicker-induced change blindness paradigm (Field & Cox, 2008). In this task, two photographs containing substance-related and neutral objects are repeatedly

and rapidly presented on a computer screen, closely resembling a flicker on the screen. These images are similar to one another in every other aspect apart from the objects they contain: either substance-related or neutral. Participants observe the rapid stream of images on the computer screen until they are able to identify the differences between the two images. The objects individuals attend to are inferred from the type of difference they identify. If participants notice the substance-related change rather than the neutral change, this is interpreted as a tendency to favor and attend to substance-related objects. One study demonstrated that heavy drinkers more often noticed alcohol-related changes than neutral ones, suggesting an attentional bias to such stimuli in those heavier drinkers (Jones et al, 2006).

Tasks incorporating eye-tracking paradigms have been the most recent breakthrough in attempting to study attentional bias in the laboratory (Miller & Fillmore, 2010). In assessing for attentional bias, computer tasks, such as the visual dot probe, are able to integrate this technology into their administration (Field & Cox, 2008; Weafer & Fillmore, 2012). Such implementation of eye-tracking technology allows for researchers to determine where an individual is looking and, primarily, the amount of time an individual spends fixating on an image. In the visual dot probe task individuals are asked to look at both alcohol-related and neutral stimuli which are presented side-by-side simultaneously on a computer screen. Instead of relying on reaction time as a primary measure of attention in this task, time spent looking at stimuli can be considered. Eye-tracking software monitors the amount of time an individual visually attends to each of these images in this task, with longer fixation times on alcohol-related images compared

to the neutral images providing an indication of attentional bias (Miller & Fillmore, 2010).

Monitoring fixation time as opposed to reaction time or other performance-based data provides a more straightforward measure of attention. Determining where an individual is looking is an unambiguous way to determine where they are choosing to allocate their attention as opposed to extrapolating from, for instance, how quickly he or she reacts to a probe. Eye-tracking also opens up a means to measure attentional bias without the need of using any performance-based tasks. Images can simply be presented to an individual and they could be asked to scan a scene, such as in the scene inspection paradigm (Weafer & Fillmore, 2012). An added bonus of eye-tracking is not only a more robust means of detecting attentional bias and allowing for novel approaches to emerge but, as previously mentioned, the technology can also be used with currently existing paradigms such as computer-based tasks.

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. Ideally, attentional bias and gaze time to stimuli would be observed in a more naturalistic, or *in vivo*, environment which more closely represents what an individual is likely to encounter outside of the laboratory.

Portable eye-tracking glasses, a recent development in eye-tracking technology, allows for such observations to be made. Recent advances in eye-tracking technology have led to portable eye-tracking eyewear that make it possible for such determinations to be made. Eye-tracking glasses (Tobii Technology, Sweden) can be worn by any individual just as they might wear any other pair of glasses. 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 glasses themselves are connected via a wire to a portable battery pack which also acts as a recorder of both the video of what the individual is looking at and their pupil movements. Apart from the cord connecting the battery pack to the glasses, the entire apparatus is wireless and is not attached to any other component, allowing the individual using the equipment complete freedom of head and body movement to navigate and visually explore any environment in which they are placed.

Measuring *in vivo* Attentional Bias

In vivo observation of attention made possible by eye-tracking glasses paves the way for new and exciting methodology in attentional bias research. One means by which *in vivo* attention might be measured is simply allowing individuals to freely explore an environment with the eye-tracking glasses equipped. This environment could be modified to represent a bar- or lounge-like or other recreational environment that one is likely to encounter alcohol, but still be contained within the laboratory setting. An individual visually observing such an environment would encounter alcohol "target" objects (i.e., bottles or cans of alcohol) and paired neutral, non-alcohol "target" objects (i.e., bottles or cans of non-alcohol beverages) among other items placed and scattered throughout. Attentional bias could then be determined simply by measuring the fixation time an individual spends attending to the alcohol versus neutral target objects, with more time spent observing alcohol objects being an indicator for attentional bias to alcohol.

Eye-tracking glasses allow for a substantial degree of flexibility and freedom for not just the individual wearing the glasses, but also in establishing new experimental designs. 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, it provides advantages over traditionally used measures for observing attentional bias. First, actual alcohol-related objects can be studied as targets of attentional focus instead of pictorial representations on computer displays. Moreover, the greatest advantage for this technology is that it allows for attention to these actual objects can be examined *in vivo* as the individual

explores and encounters these objects in a naturalistic environment. The space of an entire room can be utilized for experimental purposes instead of focusing only on a computer screen in a testing room. Physical objects can be used as target stimuli instead of static images and the setting can be modified to emulate environments an individual might expect to encounter while drinking outside of the laboratory as opposed to a sterile or foreign laboratory space. Instead of using performance or computer-based tasks, individuals can now be placed into environments that better represents their own drinking experiences. Since glasses allow for an individual to behave more naturally than they would using traditional eye-tracking technologies, and they can experience an environment that better represents their own real life experiences, the glasses provide a substantial increase in presenting an ecologically valid means of assessing attentional bias. As such, behaviors and processes detected while an individual is in such a setting are more likely to capture what actually happens in the real world outside of the laboratory. The purpose of developing new means of measuring attentional bias is to ultimately move the field closer to having an understanding of how such a process works in the natural environment.

Challenges of *in vivo* Attentional Bias

The advantages offered by implementing a task with increased ecological validity and ample flexibility come at a cost. One concern about testing in such a setting that is meant to represent one's natural environment is accounting for the novelty of this experience. An individual in a novel naturalistic environment could fail to identify or adequately attend to targets or may be distracted by other stimuli that are not experimentally relevant. Computer tasks, such as the visual dot probe task, often restrict

an individual's focus to only what are considered target stimuli, and therefore prevent the participant from allocating attention elsewhere. The demands of these tasks provide an individual with a limitation that is often reciprocal in nature: attention paid to one item comes at the cost of the other, and often only two items are available to choose from when considering where to allocate attention. Computer tasks such as the scene inspection paradigm have made strides towards addressing the artificiality of a limited-choice task such as the visual dot probe (Weafer & Fillmore, 2012). Still, such tasks are a far cry from emulating an actual immersive environment in which stimuli are physically encountered and those tasks likely fail to come upon the issues of novelty that are likely to arise during *in vivo* exposure.

In an *in vivo* situation, there are no limitations imposed in what an individual might choose to attend to. A person might opt to look at target stimuli in a room, or may choose to look at any non-experimental items or features. Individuals tend to allocate significantly more attention to stimuli that have never been encountered compared to non-novel stimuli (Fagan & Haiken-Vasen, 1997). A stimulus may be considered novel when it has never been seen before or if it is being seen in a new environmental context (Duckworth, Bargh, Garica & Chaiken, 2002). Over time and with enough exposure, habituation occurs and objects become less salient due to their novel properties (Tipper, Borque, Anderson & Brehaut, 1989). At the point of habituation, stimuli which are no longer attention-grabbing due to their novelty must have some other characteristic that makes them a focus of attention, such as having an appetitive quality.

Since novelty is likely to play a significant role in impacting attention in an *in vivo* environment, attentional bias is unlikely to be immediately demonstrated because

visual attention would be allocated to all the new stimuli in any given context where their choices for stimuli to attend to are not limited. However, after spending enough time in a room and becoming familiar with the objects within it, fixation times spent on those items likely indicates that they are appealing for reasons beyond being new. In the case of alcohol-related stimuli, this could be how attentional bias emerges in real world settings.

This approach to measuring attentional bias has not been utilized before. In considering how to utilize the technology, there are substantial challenges that implementing portable means of eye-tracking present which must be noted. Novelty of the environment and stimuli encountered, as mentioned before, is an important consideration in attempting an *in vivo* design of measuring attentional bias. Individuals would have to be given enough time to take in and be exposed to their surroundings so that attention being observed is due to some characteristic of the objects other than their simply being new. Additionally, while there is greater ecological validity by allowing the individual to freely move and observe objects in their environment, there is also a substantial loss of control that must be surrendered in order for this to take place. Individuals could opt to look at objects the experimenter has identified as a target item, but they might also attend to objects or locations which are not experimentally relevant.

Despite these challenges, there are significant advantages afforded by taking this novel approach to assessing attentional bias. *In vivo* examination of allocation of attention provides a means to observe individuals in a natural environment representing one they may encounter in a real world drinking episode. As previously mentioned, findings obtained from taking an *in vivo* approach are far more likely to be representative of how attentional bias is demonstrated outside of the laboratory than any other currently

employed means of measuring attention. Another benefit of *in vivo* experimentation is the relative simplicity of the task compared to many others. An *in vivo* task is meant to, as much as possible, emulate an individual's real world experience. As such, the participant is encouraged to behave as naturally as possible and given very little in the way of restrictions in behavior or complicated task instructions. In fact, the *in vivo* task this research utilized simply instructed participants to observe their surroundings, requiring no additional cognitive or behavioral demands. Another advantage afforded by the eye-tracking glasses is the ability for the experimenter to observe the participant's eye movements and perspective remotely and in real time. This allows the participant to be physically apart from the experimenter and therefore behave more naturally while still providing the experimenter with a means to ensure that the testing protocol is being followed and the technology is working properly.

Purpose of Dissertation Research

The research conducted for this dissertation sought to determine how attentional bias emerges in an *in vivo* experimental setting as well as determine the influence of alcohol consumption on attentional bias. Participants were tested in a novel *in vivo* task using portable eye-tracking glasses. Study 1 of the dissertation examined attentional bias to alcohol-related objects across two identical testing sessions in order to understand the impact of novelty on allocation of attention in a room representing a bar-like environment one would likely encounter outside of the laboratory. Study 2 tested individuals using the same *in vivo* task in response to a 0.30 g/kg dose of alcohol, a 0.65 g/kg dose of alcohol and a placebo. Participants also completed the visual dot probe task to measure and compare their attentional bias in a more traditionally implemented task to the novel *in*

vivo approach utilized in this research. Additionally, this dissertation addresses the potential role of attentional bias in maintaining a drinking episode and adds to the limited research available regarding the effect of alcohol consumption on attention.

Study 1

The first study in this research utilized a novel approach to measuring attentional bias via an *in vivo* task with the aid of eye-tracking glasses. The primary purpose of this first *in vivo* assessment of attentional bias to alcohol objects was to evaluate the effects of stimulus novelty on attentional bias. Although eye-tracking glasses have the potential to provide a more ecologically-relevant assessment of attentional bias to alcohol compared to image-display tasks such as the visual dot probe, 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 novel stimulus is one that has never been encountered before or is being seen in a new context (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. It was 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. An example of the eye-tracking apparatus and how the apparatus would be worn during testing can be found in Figure 1.

Figure 1. *Eye-tracking glasses with portable battery pack (left) and the eye-tracking glasses as they would be worn during an in vivo assessment of attention (right).*

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. 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, no explicit information about assessing their attention to target objects in the room was provided. 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. Figure 2 provides examples of item pairings and locations used in the *in vivo* assessment.

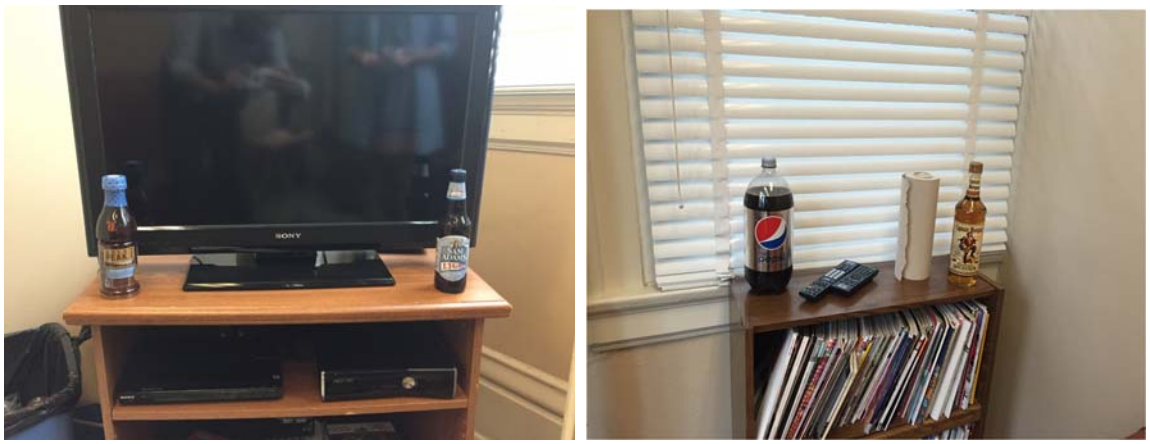

Figure 2. *Two of the alcohol and neutral item pairing as used in the in vivo assessment of attention.*

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 broken down by gender are presented in Table 1. This table shows that drinking habits did not significantly differ between men and women participants. 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.

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	9.9	9.0	0 - 25	
TLFB - Drunk Days	9.79	9.3	0 - 39	10.1	8.6	0 - 27	
TLFB - Drinking Days	24.2	11.0	7 - 47	24.9	12.7	8 - 65	
TLFB - Total Drinks	85.8	74.1	7 - 289	143.8	99.5	39 - 385	
AUDIT	7.1	3.8	1 - 14	10.5	4.4	6 - 21	*
Demographics							
Age	23.9	3.1	21 - 30	26.19	4.2	21 - 34	

Note. Gender contrasts were tested by one-way between subjects ANOVAs. Data labeled TLFB is from the Timeline Follow-Back.
*$p < .05$

Fixation Times

Fixation times are plotted in Figure 3. 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, $F(1, 34) = 6.071$, $p = .019$, $\eta_p^2 = 0.15$. 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, $t(34) = -0.309$, $p = .76$, $d = 0.05$. 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, d = 0.33. 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, d = 0.32. No such decline was found for fixation time to alcohol objects between sessions, $t(34) = -0.645$, p = .52, d = 0.11.

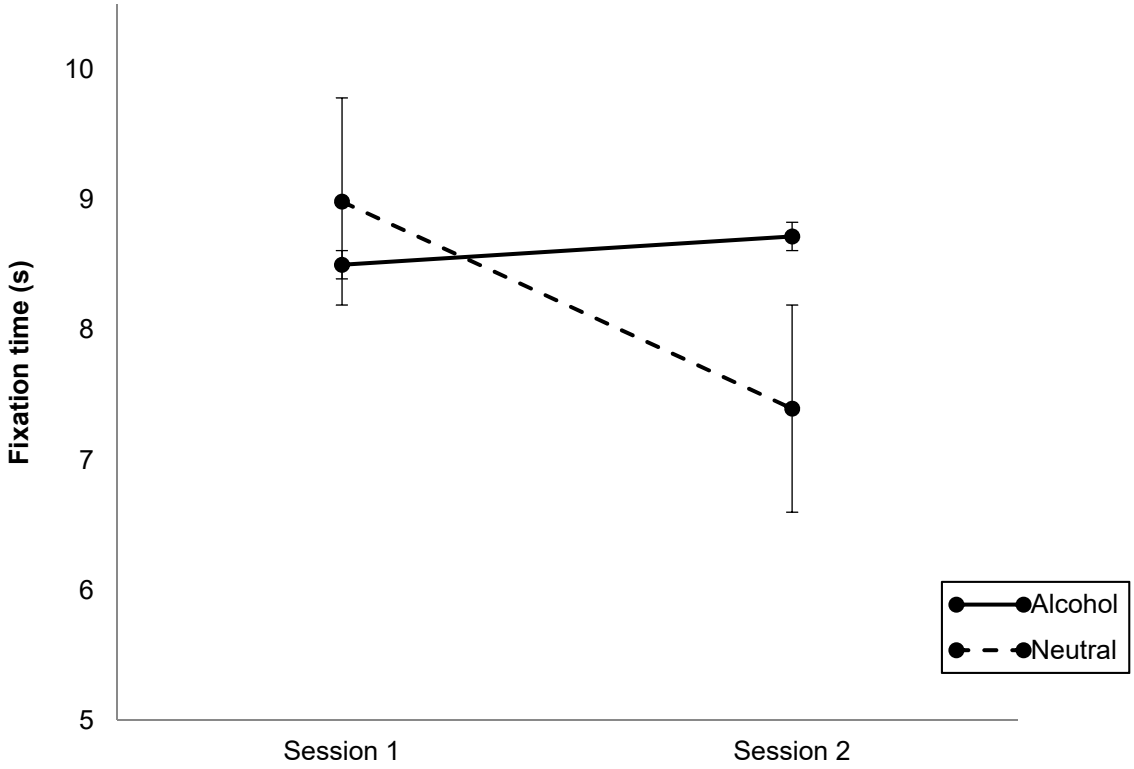

Figure 3. *Average fixation times to alcohol and neutral beverages during the in vivo assessment of attentional bias for both experimental sessions.*

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

The consistency of individual differences in fixation times across the five one-minute exposures in a session was examined 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.

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.

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 4 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.

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.

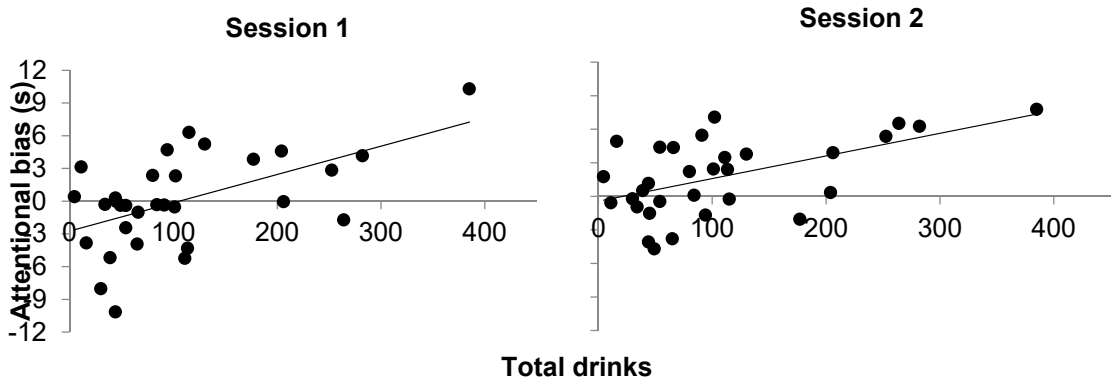

Figure 4. *Relationship between an individual's attentional bias scores and their total drinks over the past 90 days on the TLFB for sessions 1 and 2.*

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 reported 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. This 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. Repeated exposure to the environment was included 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. Greater internal consistency of fixation times during session 2 was also observed, 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 the use of *in vivo* attentional bias tasks.

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. This study sought to limit restriction on participants' behavior during the *in vivo* assessment and they were 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. This could be addressed by studying 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. First, it is important to compare *in vivo* assessments of attentional bias with those obtained by computer display tasks. Such psychometric-based studies would provide much needed information on the agreement among various approaches to measuring attentional bias to alcohol as a risk factor for alcohol abuse. Another area of future application is in alcohol administration. 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.

Study 2

The second study of this dissertation was designed to determine the influence of alcohol consumption on attentional bias as measured by the *in vivo* assessment of attention as well as compare findings between this novel approach and the image-display

tasks traditionally used. Using the Study 1 methodology to assess attentional bias with the eye-tracking glasses, Study 2 added the administration of various doses of alcohol as well as used the visual dot probe task as an additional measure of attentional bias. Research into the relationship between attentional bias and alcohol consumption has most frequently demonstrated that attentional bias is reduced following doses of alcohol that produce BACs of at least 80 mg/100 ml (Duka & Townshend, 2004; Weafer & Fillmore, 2013). This pattern of change in attentional bias suggests that there may be a satiation effect of alcohol consumption such that when an individual feels intoxicated, they are no longer interested in alcohol and therefore do not attend to alcohol-related stimuli to the same degree as they do sober. Findings from Roberts and Fillmore (2015) provide evidence for this satiation hypothesis by demonstrating the differences in attentional bias at different points of the BAC curve. On the ascending limb, attentional bias under a 0.64 g/kg dose of alcohol was shown to be significantly lower than the degree of attentional bias observed under placebo at the same point in time. On the descending limb, however, the degree of attentional bias under the 0.64 g/kg alcohol increased to the point that there was no significant difference between attentional bias at placebo and the 0.64 g/kg dose of alcohol. As a function of acute tolerance, the rewarding effects of alcohol begin to diminish on the descending limb of the BAC curve, suggesting that as an individual is no longer being satiated and experiencing the positive impact of alcohol, their desire to drink may also increase and with it their attentional bias to alcohol. There is additional research to suggest that at lower BACs, around 20 to 40 mg/100 ml, alcohol can increase the degree of attentional bias, possibly indicating a priming effect on motivation for the drug (Duka & Townshend, 2004; Shoenmakers, Wiers & Field, 2008). It is possible that, at

this range of doses, alcohol becomes more desirable which in turn results in greater attention allocated towards such stimuli. Such a pattern of increased attentional bias relative to placebo has been observed following a 0.30 g/kg dose of alcohol (Duka & Townshend, 2004). A limitation of these findings is that they have only been obtained using an image-display means of assessing attentional bias, such as the visual dot probe task, which brings into question their applicability to bias in real-world drinking experiences.

To address this limitation, the current study used the eye-tracking glasses to assess attentional bias following alcohol administration. Over three testing sessions, participants were given one of three possible doses of alcohol (placebo, 0.30 g/kg and 0.65 g/kg) and then, while wearing eye-tracking glasses, entered a recreational room containing several objects, including non-alcoholic and alcoholic beverages and were allowed to freely visually inspect all objects. It was hypothesized that following the placebo dose, participants would demonstrate attentional bias to alcohol during the *in vivo* assessment of attention. This attentional bias was hypothesized to be increased following 0.30 g/kg dose of alcohol due to priming. Further, it was hypothesized that the degree attentional bias observed during the *in vivo* assessment following the 0.65 g/kg dose of alcohol would be reduced compared to placebo due to satiation. The current study also involved participants completing the visual dot probe task. It was hypothesized that there would be a similar pattern between findings on the impact of alcohol consumption and attentional bias between the two tasks, such that individuals were expected to demonstrate attentional bias following the placebo dose, with a relative increase after the

0.30 g/kg priming dose and a relative decline in attentional bias following the 0.65 g/kg high dose.

Methods

Participants

Twenty-three adults (10 men and 13 women) between the ages of 21 and 34 years participated in this study (mean age = 24.6, SD = 3.9). The racial make-up was as follows: Asian (n = 1), African American (n = 2), Native Hawaiian/Pacific-Islander (n = 1), Caucasian (n = 17) and Other (n = 2). 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 being a current, regular drinker with 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. Individuals reporting any psychiatric disorder, CNS injury, or head trauma did not participate, nor did those reporting dependence on illicit drugs. 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.

The sample size used in this study was based on previous work from our laboratory where samples of moderate to heavy drinkers using 20 participants have detected alcohol effects on comparable attentional bias measures with medium to large effect sizes (d = 0.81; partial η^2 = 0.17 - 0.42).

Materials and Measures

Eye-tracking glasses. The *in vivo* assessment of attention used in this study was identical to the one in Study 1. Refer to the description of this task from Study 1.

Visual dot probe task. The task was operated using E-Prime experiment generation software (Psychology Software Tools, Pittsburgh, PA) and was performed on a PC. Fixations were measured using a Tobii T120 Eye Tracking Monitor (Tobii Technology, Sweden). Stimuli were presented on the Tobii Monitor and dual embedded cameras tracked participants' gaze locations. Participants were seated with their heads approximated 60 cm in front of the computer with a free range of head and neck motion. Gaze locations were sampled at 120 Hz and fixations were defined as gazes with standard deviations less than 0.5 degrees of visual angle for durations of 50 ms or longer.

This task measured attentional bias towards alcohol-related images. Participants viewed a neutral and alcohol image presented side-by-side on a computer monitor for 1000 ms. Upon offset of the images, a visual-probe appeared which participants responded to by pressing a key corresponding to the probe's location. The pictures consisted of 10 alcohol-related images (alcohol beverages) that were paired with 10 neutral images (non-alcohol beverages). The task also included additional "filler" trials that consisted of 10 pairs of non-beverage neutral images to reduce the likelihood of habituation to the alcohol target stimuli. Each pair was presented 4 times, totaling 80 trials with 40 critical trials. For each critical trial where target images were presented, the total duration of all fixations directed towards each image type (i.e., alcohol or food targets and neutral images) was calculated. These values were averaged across trials to produce a mean fixation time for each image type. The visual dot probe task was

implemented in this study to demonstrate the effects of alcohol consumption on attentional bias, as it has been used in previous research for the same purpose (Weafer & Fillmore, 2013; Roberts & Fillmore, 2015).

An additional food-stimuli version of the visual dot probe task was utilized in this study that used an entirely different set of stimuli, but was operationally identical to the alcohol-stimuli version of the task. This alternative version of the visual dot probe task contained 10 target images of food paired with 10 neutral, non-food images that were designed to match the food images for size, color and complexity. The task also consisted of an additional 10 "filler" image pairings. This version of the task was utilized to demonstrate that the influence of alcohol consumption on attentional bias is specific only to alcohol-related stimuli and not on general attentional bias to any other appetitive stimuli.

Timeline Follow-Back (TLFB). Refer to the description from Study 1

Alcohol Use Disorders Identification Test (AUDIT). Refer to the description from Study 1.

Subjective Effects Questionnaire. Participants provided ratings of subjective states using a visual analogue scale (Van Dyke & Fillmore, 2014). They rated 15 items (I feel depressed; I have no motivation; I feel hungry; I am willing to drive a car; I feel sedated; I feel happy; I feel intoxicated; I find it hard to concentrate; I feel thirsty; I feel nervous; I feel irritable; I feel confident; I feel I am legally able to drive a car; I feel stimulated/alert; I feel down) by drawing vertical line on a 100mm long scale ranging from "not at all" at one end to "very much" at the other. Additionally, this questionnaire included an area for individuals to estimate their BAC, with values ranging from 0

mg/100 ml to 160 mg/100 ml, with 80 mg/100 ml falling in the middle of the scale. The BAC estimation scale was included as another means to determine how intoxicated an individual was feeling after alcohol administration. Previous research has shown that these scales are sensitive to changes in subjective effects that occur over the time course of an alcohol dose (e.g., Fillmore, 2001). This questionnaire was administered as part of a standard test battery and in this study served as a sort of manipulation check for the administration of alcohol. To this end, the items "I feel intoxicated" and the estimated BAC are the items of primary interest in this study, as they have more greatest conceptual relevance to the idea of satiety to alcohol.

Procedure

The study took place over the course of four test sessions at the Behavioral Pharmacology lab in the Psychology Department. During the first session, informed consent was obtained, and a zero BAC was confirmed by breath analysis. Illicit drug use was also assessed via urine analysis (ICUP Drug Screen, Instant Technologies). Positive screens for drugs other than tetrahydrocannabinol (THC) during a testing session that involved alcohol administration resulted in rescheduling of that session. Those whose urine tested positive for THC were allowed to continue the session only if they abstained from using THC for at least 24 hours prior to the sessions. No female volunteers who were pregnant or breast-feeding participated in the research (Icon25 Hcg Urine test, Beckman Coulter). Screenings were followed by completion of questionnaires on demographics, general health status, drug use, and the TLFB and AUDIT. Participants were then acquainted with the eye-tracking glasses. The instructions given and the task that participants completed was identical to what was done in Study 1. After becoming

familiarized with the eye tracking glasses and the task, participants completed the alcohol and food version of the visual dot probe task. The order for completion of both versions of the visual dot probe task was counterbalanced across participants, but the order remained consistent for the individual for all test sessions.

Participants' attended an additional three test sessions that were designed to test the acute effects of alcohol on the measures of attentional bias. As in session 1, participants provided a breath sample to verify a zero BAC and a urine sample for illicit drug screening. After a zero-BAC and negative urine analysis were confirmed, participants were administered either a placebo, a 0.30 g/kg or 0.65 g/kg dose of alcohol. The 0.30 g/kg dose of alcohol was intended to produce an average peak BAC of 30 mg/100 ml, and the 0.65 g/kg alcohol dose was to intended to produce an average peak BAC of 80 mg/100 ml. All participants received one dose per session and received one of each possible dose across all three test sessions. The order of dose administration given was counterbalanced across participants, and participants were blind to dose order. The alcohol beverage was served as one-part alcohol and three-parts carbonated mix divided equally into two glasses. The placebo consisted of four-parts carbonated mix that matched the volume of the 0.30 g/kg dose. Five milliliters of alcohol were floated on the top of each placebo glass, and the glasses were sprayed with an alcohol mist that resembles condensation and provides an alcohol odor. Participants drank both beverages within six minutes.

At 25 minutes post-administration, participants began the *in vivo* assessment of attentional bias as it was conducted in session 1 followed by the visual dot probe tasks. Testing was completed roughly 75 minutes following dose administration, with all testing

done on the ascending limb and at the peak of the BAC curve. BAC was monitored throughout the session via breath analysis, starting at 25 minutes after administration with breath samples being gathered every 20 minutes during testing. Participants remained in the lab until they were at or below a 20 mg/100 ml BAC level. The inter-session interval ranged from three to four days and all sessions were completed within two weeks. At the conclusion of the final testing session participants were paid and debriefed.

Criterion Variables and Data Analyses

***In vivo* Assessment of Attention**

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 (stimuli; alcohol, neutral) X 3 (dose; placebo, 0.30g/kg, 0.65g/kg) repeated measures analysis of variance (ANOVA). Simple effects were analyzed using paired-samples *t* tests for each dose condition to determine when significant attentional bias was observed.

Visual Dot Probe Tasks

On the visual dot probe task, an average fixation time was calculated across all forty critical target trials, where greater average fixation time to alcohol or food stimuli compared to neutral stimuli was indicative of attentional bias. For both the alcohol-

stimuli and food-stimuli versions of the task, fixation times were analyzed by a 2 (stimuli; alcohol/food, neutral) X 3 (dose; placebo, 0.30g/kg, 0.65g/kg) repeated measures analysis of variance (ANOVA). Simple effects were analyzed using paired-samples *t* tests for each dose condition to determine when significant attentional bias was observed.

Additional Analyses

The relationship between attentional bias to alcohol-related objects and drinking habits obtained from the TLFB was examined via correlational analyses. The relationship between subjective effects and attentional bias to alcohol-related objects were also examined via correlational analyses. Changes in BAC for active dose conditions were analyzed via a 2 (dose; 0.30g/kg, 0.65g/kg) x 3 (time; 25 min, 45 min, 65 min) ANOVA to cover the times at which testing took place. Additionally, all analyses in this study were 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 4. As in Study 1, men and women did not significantly differ from one another in their drinking habits, and drinking habits show that participants were regular drinkers and were comparable to those who have demonstrated attentional bias in previous studies (Miller & Fillmore, 2010; Roberts, Fillmore & Milich, 2012). Some participants reported past

month use of nicotine (n = 7), marijuana (n = 6), and sedatives (n = 1). Participants verbally confirmed abstinence from substance use during the 24 hours prior to each session with breath and urine analysis used to confirm a zero BAC and no drug use respectively.

Table 4
Mean Drinking Habits and Demographics Measures by Gender

	Group					
	Women			Men		
	M	*SD*	*Min - Max*	*M*	*SD*	*Min - Max*
Drinking Habits						
TLFB - Binge Days	7.4	8.5	0 - 22	3.6	3.7	0 - 9
TLFB - Drunk Days	8.2	7.5	1 - 23	5.5	5.3	0 - 16
TLFB - Drinking Days	25.2	14.7	6 - 51	33.0	20.6	10 - 68
TLFB - Total Drinks	89.1	78.6	15 - 263	102.8	70.5	10 - 209
AUDIT	7.6	4.1	2 - 15	8.3	4.0	2 - 15
Demographics						
Age	24.5	4.4	21 - 34	24.9	3.4	21 - 31

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

Blood Alcohol Concentrations

BACs at all time points for the active dose conditions are presented in Table 5. Testing was completed within the first 70 minutes following dose administration, thus the first three time periods reported on this table are ones in which testing was taking place. This table shows that following the 0.30 g/kg alcohol dose, participants' BAC steadily declined over the first 65 minutes (mean BAC = 30.8 mg/100 ml) and following the 0.65 g/kg alcohol dose, participants' BAC steadily rose over the first 65 minutes (mean BAC = 72.7 mg/100 ml). A 2 (dose) x 3 (time) ANOVA identified a main effect of dose,

$F(1,22) = 235.9$, $p = .000$, $\eta_p^2 = 0.91$ which was found due to the overall higher BACs produced in the 0.65 g/kg dose compared to those observed following the 0.30 g/kg dose. No main effect of time was found, $p > .05$. A dose X time interaction was observed, $F(1, 22) = 6.194$, $p = .004$, $\eta_p^2 = 0.21$, which was due to the decline in BACs for the 0.30 g/kg dose compared to the rise observed following the 0.65 g/kg dose. No detectable BAC was observed at any time point in the placebo condition.

Table 5
Mean Blood Alcohol Concentrations for all dose conditions (BAC)

	0.30 g/kg				0.65 g/kg			
Minutes past dose	25	45	65	85	25	45	65	85
BAC								
M	34.3	30.8	25.9	22.6	68.9	72.7	79.8	66.6
SD	9.5	8.5	7.4	6.5	20.9	14.5	12.3	12.4

Note. All BACs are reported as mg/100 ml.

In vivo Assessment of Attentional Bias

Figure 5 shows the fixation times to stimuli for all doses on the *in vivo* assessment of attention. As the figure illustrates, fixation times between alcohol and neutral stimuli on the *in vivo* assessment did not significantly differ from one another following any of the doses of alcohol administered. A 2 (stimuli) x 3 (dose) ANOVA yielded no main effect of stimuli or dose on the *in vivo* task, *ps* > .05. Additionally, there was no significant stimuli by dose interaction. Following placebo, no significant attentional bias was found for the *in vivo* assessment. For the active doses, paired *t* tests demonstrated no significant difference in fixation times between alcohol and neutral stimuli on the *in vivo* tasks, *ps* > .05. Taken together, attentional bias was not observed at any point on the *in vivo* assessment nor was any significant pattern of changes in fixation time across doses able to be discerned.

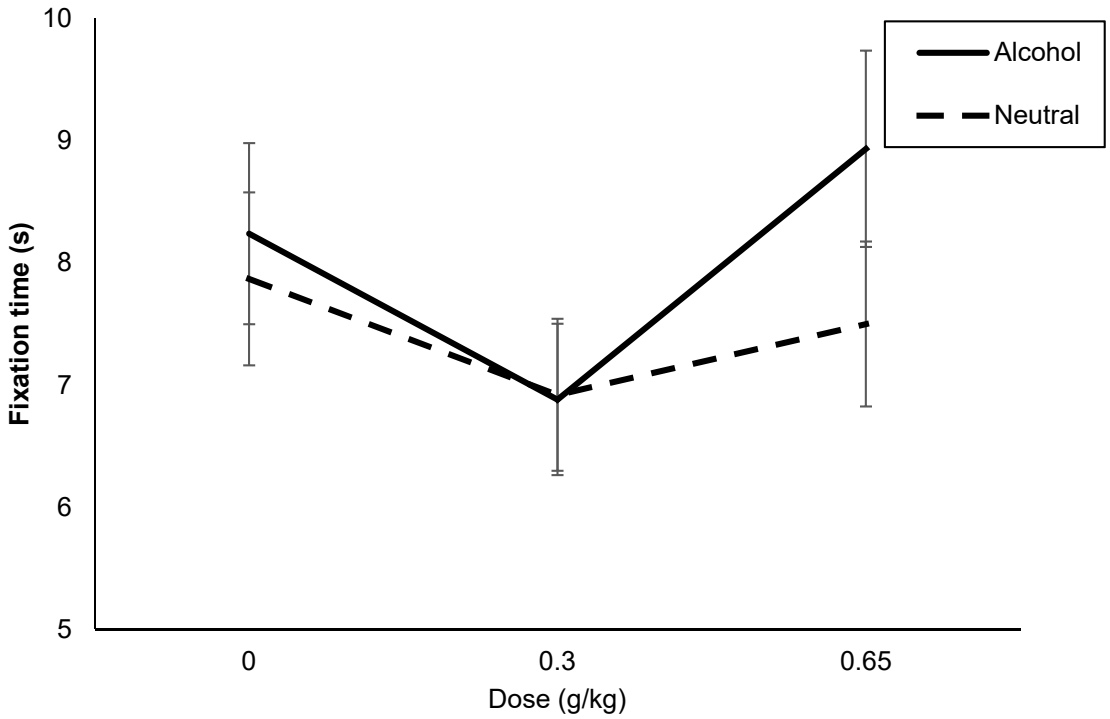

Figure 5. *Average fixation time to alcohol and neutral stimuli for all exposures during the in vivo assessment of attention.*

Visual Dot Probe Assessment of Attentional Bias

Figure 6 shows the fixation times to stimuli for all doses on the visual dot probe task, where the difference in fixation times between alcohol and neutral stimuli is shown to shrink as alcohol dose increases. A 2 (stimuli) x 3 (dose) ANOVA yielded main effects of dose, $F(1,22) = 6.93$, $p = .015$, $\eta_p^2 = 0.24$, and stimuli, $F(1,22) = 5.22$, $p = .009$, $\eta_p^2 = 0.19$. No stimuli by dose interaction was found. Figure 6 shows that the main effect of stimuli is attributable to consistently more fixation time spent on alcohol images compared to neutral images across all doses of alcohol. Furthermore, the main effect of dose is due to the overall decrease in fixation time as the dose of alcohol increases. Paired-sample *t* tests indicated that there was significant attentional bias at placebo, $t(22) = 1.99$, $p = .03$, $d = 0.44$, and following the 0.30 g/kg alcohol dose, $t(22) = 1.89$, $p = .036$, $d = 0.23$. However, following the 0.65 g/kg alcohol dose, the magnitude of attentional

bias has diminished to the point that differences between the two stimuli are no longer significant, $t(22) = .72$, $p = .241$, $d = 0.09$.

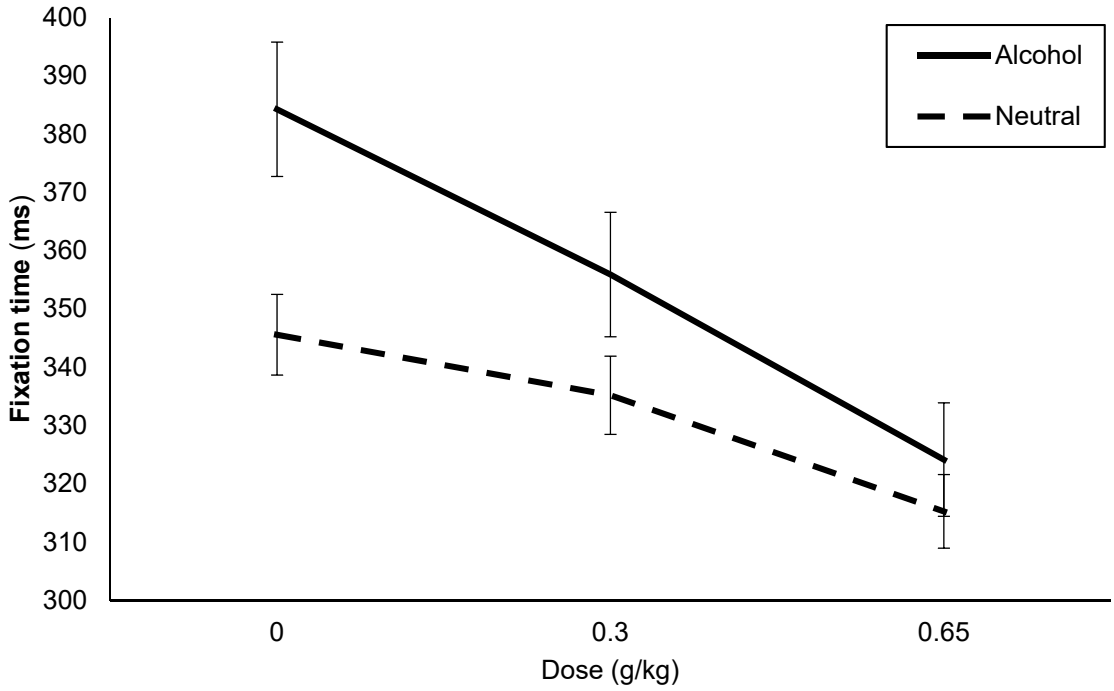

Figure 6. *Fixation times to alcohol and neutral stimuli on the visual dot probe task.*

Individuals also performed a visual dot probe task that instead used food stimuli. Fixation times to stimuli for all doses on this version of the visual dot probe task can be found in Figure 7. This figure illustrates how at all doses of alcohol there is a consistent attentional bias for food. As with alcohol, a 2(stimuli) x 3 (dose) ANOVA yielded a main effect of dose, $F(1,22) = 17.61$, $p = .001$, $\eta_p^2 = 0.44$, and stimuli, $F(1,22) = 3.25$, $p = .048$, $\eta_p^2 = 0.13$. There was no stimulus by dose interaction. The main effect of stimuli is the result of consistently greater fixation times to food stimuli compared to the neutral, non-food pairings. A main effect of dose is due to the overall decline in fixation times. Difference in fixation times are significant at all doses, $ts(22) = 2.45\text{-}4.19$, $ps < .05$, $ds = 0.34 – 0.48$, indicating attentional bias for all dose conditions. Unlike attentional bias to

alcohol-related stimuli, there was no decrease in the magnitude of attentional bias to food-related stimuli as a function of alcohol dose.

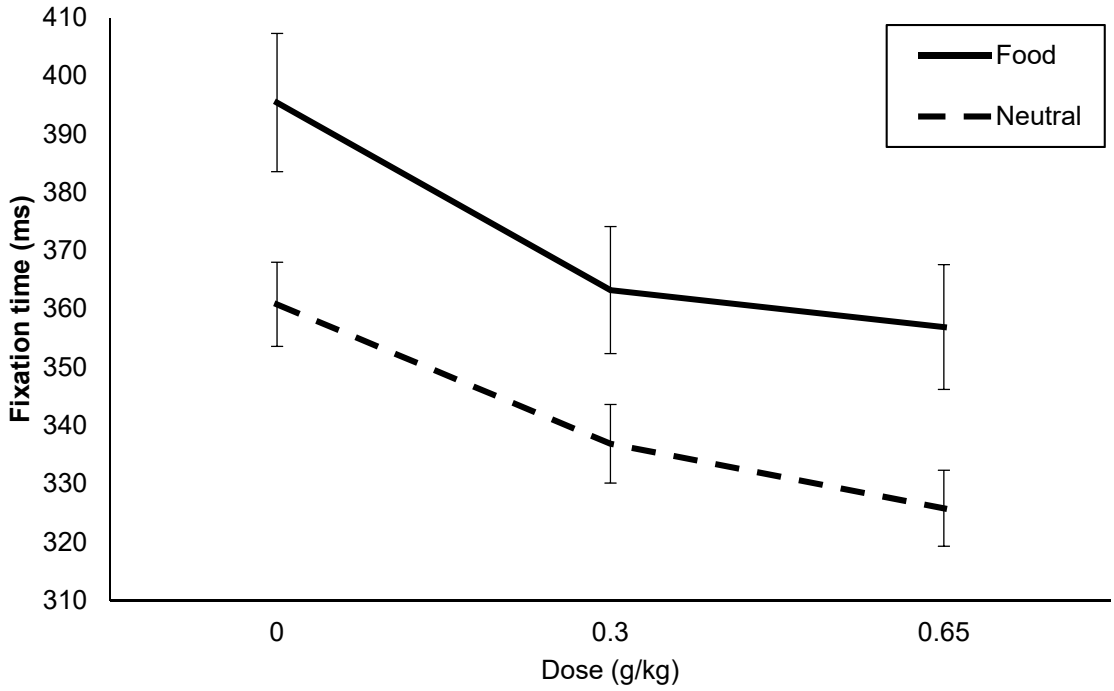

Figure 7. *Fixation times to food and neutral stimuli on the visual dot probe task.*

Reliability of Tasks

In order to evaluate the internal consistency in measurements of fixation time observations on each task, coefficient alpha was calculated. In the *in vivo* task, a coefficient alpha of .83 was obtained for alcohol fixation times across the three dose administration days. Looking at the same parameters for the visual dot probe task, a coefficient alpha of .86 was found. These scores suggest that each task was obtaining reliable and consistent measurements for each individual across all dose conditions.

Inter-Task Correlations

Results from regression analyses comparing fixation time to alcohol stimuli between both the *in vivo* and visual dot probe tasks can be found in Table 6. Regression analyses of time spent observing alcohol stimuli showed no significant associations

between tasks on any of the dose administration days for all doses, *ps* > .05. Therefore, attention allocated to alcohol stimuli on one task did not predict attention to alcohol stimuli on the other task.

Table 6
Regression analyses of fixation time to alcohol in the in vivo and visual dot probe tasks

Dose session	*b*	*t*	*p*	r^2
0.0 g/kg	1.94	0.69	.494	.023
0.30 g/kg	5.40	1.68	.107	.119
0.65 g/kg	-3.30	-1.08	.292	.053

Associations of Attentional Bias with Drinking Habits

As in study 1, regression analyses using drinking habit measures as a predictor of attentional bias were examined to determine if participants reporting heavier alcohol consumption would also displayed 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 7 reports the results of the regression analyses. Individual differences in drinking were not significantly related to participants' attentional bias scores in any dose condition, *ps* > .05.

Table 7

Regression analyses of attentional bias scores with Drinking Habits on the TLFB by dose session for in vivo assessment of attention and visual dot probe task

	In vivo Assessment				Visual Dot Probe Task			
	b	*t*	*p*	r^2	*b*	*t*	*p*	r^2
0.0 g/kg								
Total Drinks	3.12	0.91	.375	.038	-0.07	-0.39	.702	.007
Binge Days	0.49	1.58	.129	.106	-0.01	-0.47	.640	.011
Drunk Days	0.36	1.17	.256	.061	-0.01	-0.64	.526	.019
Drinking Days	0.43	0.52	.606	.013	0.01	0.18	.858	.002
0.30 g/kg								
Total Drinks	-2.94	-0.64	.526	.019	0.26	0.88	.390	.035
Binge Days	-0.11	-0.26	.801	.003	0.03	1.14	.268	.058
Drunk Days	-0.47	-1.19	.249	.063	0.01	0.36	.722	.006
Drinking Days	-0.44	-0.40	.690	.008	-0.01	-0.10	.925	.000
0.65 g/kg								
Total Drinks	2.92	0.99	.330	.045	0.31	1.17	.256	.247
Binge Days	0.34	1.23	.232	.067	0.02	0.72	.478	.024
Drunk Days	0.25	0.95	.351	.042	0.03	1.49	.149	.097
Drinking Days	-0.01	-0.01	.990	.000	0.04	0.60	.555	.017

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.

Associations of Attentional Bias with Subjective Effects

Table 8 details the subjective levels of intoxication and estimated BAC for each of the three doses of alcohol administered in the study. As can be seen from Table 8, subjective intoxication and estimated BAC climbed in a dose dependent matter, where participants endorsed higher levels of each at the higher doses of alcohol. Similar to drinking habits, regression analyses performed using subjective effects as a predictor of bias scores on both tasks for each dose session yielded no significant relationships, *ps* > .05.

Table 8

Mean, standard deviation and minimum, maximum values on subjective effects questionnaire items subjective intoxication and estimated BAC

	Subjective Intoxication			Estimated BAC (mg/100ml)		
	M	*SD*	*Min - Max*	*M*	*SD*	*Min - Max*
0.0 g/kg	10.83	16.56	0 – 60	30	27	0 – 100
0.30 g/kg	29.61	17.53	1 – 68	52	29	1 – 110
0.65 g/kg	63.91	20.19	21 – 100	79	33	15 – 135

Note. Values for subjective intoxication reported on a 0 - 100 mm visual analog scale.

Dose Order

Based on previous findings, *in vivo* attentional bias was expected to be observed in the sober state on both tasks. This was anticipated because, until this study, the *in vivo* assessment of attention had only been performed in the sober state. For this study, the placebo dose condition is considered the "sober state" condition. Given that habituation is believed to be a driving factor behind the emergence of *in vivo* attentional bias, it is possible that multiple sessions could impact an individual's habituation to alcohol stimuli. In turn, this habituation could impact attentional bias to alcohol in the sober state. For this reason, dose order was examined via simple effects analysis in order to determine if the magnitude of attentional bias in the placebo condition differed depending on whether the individual had this condition first, second or third in the study. Fixation times to alcohol and neutral stimuli and their paired sample *t* test comparisons are reported in Table 9. As the table demonstrates, no significant attentional bias was observed under placebo regardless of which testing session the placebo was administered in, indicating that order did not influence *in vivo* attentional bias.

Table 9

Fixation times to alcohol and neutral stimuli in placebo session for each of the three session orders of the placebo condition and results of comparisons in each session

Placebo session	*Alcohol*	*Neutral*	*t-score*	*p*
1st	7.89	7.62	0.215	.418
2nd	9.69	10.72	-0.502	.683
3rd	7.23	5.40	1.038	.170

Note. Values for fixation times are in seconds. Contrasts done via one-way paired sample t-tests.

Discussion

This purpose of this study was to identify the effects of alcohol administration on *in vivo* attentional bias. It was hypothesized that attentional bias during the *in vivo* assessment of attentional would be observed among participants following administration of the placebo. This hypothesis was informed by the findings of study 1, where *in vivo* attentional bias was observed for participants in a sober state. For study 2, this sober state is most similar to the placebo condition where no alcohol was administered (i.e., a sober state), therefore it was expected that attentional bias would be observed following placebo. This hypothesis was not supported. Likewise, the hypotheses that *in vivo* attentional bias would increase relative to placebo following the 0.30 g/kg priming dose of alcohol or diminish relative to placebo under the 0.65 g/kg dose were also not supported, as attentional bias was not observed under either of those conditions during the *in vivo* assessment of attention. Taken together, there was no evidence to suggest any particular pattern of *in vivo* attentional bias that emerged as a result of alcohol consumption.

An additional goal of this study was to draw direct comparisons between *in vivo* attentional bias and attentional bias as measured by an image display task. To accomplish this, participants performed the visual dot probe task in addition to the *in vivo* assessment

to check for agreement and validity between the two measures. For attentional bias as measured by the visual dot probe task, results generally supported the hypotheses, with attentional bias evident following placebo and diminishing at the 0.65 g/kg of alcohol, consistent with the satiety effect observed in other research (Weafer & Fillmore, 2013). The hypothesis that attentional bias would spike relative to placebo on the visual dot probe task following the 0.30 g/kg priming dose of alcohol was not supported, as attentional bias diminished as a function of dose, with bias getting progressively weaker following each successive dose of alcohol, further supporting the satiety effect. Although there was evidence for reliability with both measures of attentional bias, with a Cronbach's alpha of 0.83 for the *in vivo* assessment and 0.86 for the visual dot probe task, no relationship between the two was found, suggesting that the tasks are not comparable to one another and, possibly, are not adequately measuring the same phenomenon. These findings are interpreted in the broader context of what this finding could mean for the *in vivo* assessment of attentional in the General Discussion.

In order to understand why no attentional bias to alcohol was observed during the *in vivo* assessment of attention, several potential explanations were considered. An obvious explanation as to why attentional bias was not observed is that participants did not have attentional bias to alcohol in this study. Visual dot probe findings using the same set of individuals, however, provide evidence that the sample did in fact demonstrate an attentional bias to alcohol stimuli. Fixation times observed on the *in vivo* assessment were analyzed to determine if there were any relationships between bias and self-reported individual characteristics. *In vivo* bias was not significantly related to the drinking habits of individuals at any dose condition, indicating that the degree of attention allocated

during the assessment was not informed by an individual's drinking patterns. Similarly, subjective effects during any dose condition were not related to *in vivo* attention, again suggesting that how individuals were subjectively experiencing the effect of alcohol consumption was not influencing their *in vivo* attention in any significant way.

The aim of study 2 was to provide an understanding of the effects of alcohol on *in vivo* attention and draw comparisons between this novel means of observing bias and traditional measures of attentional bias. Based on findings from previous literature, it would be expected for alcohol consumption to affect attentional bias, particularly by diminishing attentional bias at higher doses that yield BACs of at least 80 mg/100 ml (Duka & Townshend, 2004; Roberts & Fillmore, 2015). Although the *in vivo* assessment in this study did not produce the expected pattern of attentional bias, the visual dot probe task utilized did demonstrate a change in bias across doses of alcohol that is consistent with findings from previous studies (Weafer & Fillmore, 2013). The dose-dependent decline in attentional bias to alcohol on the visual dot probe task observed in this study indicates that alcohol consumption results in individuals allocating less of their attention in favor of alcohol stimuli. This suggests that image-display tasks such as the visual dot probe may be the most valid and reliable means for assessing attentional bias compared to measures such as the *in vivo* assessment using eye-tracking glasses. Because attentional bias was not found at any dose condition during the *in vivo* assessment and no discernible pattern or relationship between attention and any other measures obtained in this study could be identified, the validity of such an approach to measuring attentional bias is brought into question.

General Discussion

This dissertation examined the utility of a novel means of assessing attentional bias through the use of portable eye-tracking glasses. In study 1, individuals took part in an *in vivo* assessment of attention over two test sessions in order to determine if attentional bias to alcohol would be observed. The major finding of that study was that, in the second testing session, attentional bias to alcohol emerged and appeared to be driven primarily by a maintenance of attention to alcohol-related stimuli but a decline in attention allocated towards neutral stimuli. A possible explanation for this pattern of change in bias over time is habituation to novel items. This habituation would result in less attention being paid to items such as neutral beverages as their novelty wears off. Appetitive stimuli such as alcohol beverages, however, maintain their attention-grabbing properties over that same period of time, which is when the difference in fixation times between the two stimuli begin to emerge. Expanding on this finding, the same *in vivo* assessment of attention was used in study 2, however participants were also administered alcohol prior to this assessment so that the influence of alcohol consumption on attentional bias could be observed. Study 2 also utilized the visual dot probe task, a more traditional measure of attentional bias, as another means for assessing attention to alcohol. In study 2, no attentional bias to alcohol was found during the *in vivo* assessment following alcohol administration, however a dose-dependent decline in attentional bias to alcohol was observed on the visual dot probe task.

Findings from study 2 failed to replicate those obtained from study 1. Although study 2 was methodologically distinct from study 1, the *in vivo* assessment of attention performed in both studies were identical to one another. As such, the placebo condition (i.e., the sober state condition) of study 2 was expected to yield similar findings to what

was observed on the second session of study 1 when *in vivo* attentional bias to alcohol was demonstrated. In study 2, however, no such attentional bias emerged following placebo. The lack of a consistent finding between the two studies could most easily be explained by determining what the differences are between study 1 and study 2.

Power

There were fewer participants in study 2 than were in study 1. Study 2 consisted of fewer individuals because it was a lengthier, more involved, several session study which still had a sample size comparable to previous studies were attentional bias was observed (Miller & Fillmore, 2011; Roberts & Fillmore, 2015). It is possible that fewer subjects resulted in a study that was less powered. In study 1, a Cohen's d of 0.329 was obtained for the paired-samples *t* test comparing *in vivo* attention to alcohol stimuli and neutral stimuli for session 2 of study 1, indicating a low to moderate effect size. The power to detect a difference between fixation times to alcohol and neutral stimuli observed during the *in vivo* assessment in study 1 was 0.473. In the placebo condition of study 2, which was a close approximation to session 2 of study 1 in that subjects were sober in this condition, the paired-samples *t* test analysis resulted in a significantly smaller effect size that that of study 1, with a Cohen's d of 0.066. The power in study 2 of being able to detect a difference in fixation times between stimuli types for the *in vivo* assessment was 0.061. Taken together, this suggests that the sample used in study 2 was not likely to demonstrate significant differences in attention, even if the sample size had been increased. Power and effect sizes found in study 2 were so small that no reasonable increase in sample size would likely to bring it to parity with the power of study 1.

Drinking Habits

When considering what may be different between the makeup of the samples used in both studies, it is possible that participants in study 2 simply did not have a history of drinking that would be conducive to displaying an *in vivo* attentional bias to alcohol. Several studies have demonstrated that attentional bias is related to drinking habits, such that heavier drinkers tend to allocate increased attention to alcohol-related stimuli (Townshend & Duka, 2001; Weafer & Fillmore, 2013). This raises the question of whether a lack of *in vivo* attentional bias in study 2 can be attributed simply to a sample that did not drink enough to demonstrate significant bias to alcohol. Table 10 details comparisons between drinking habits measured by the TLFB of both study 1 and study 2. As can be seen from the table, there are no significant differences in drinking habits between the two studies. Because there is no significant difference, drinking habits would not serve as the explanation for why study 2 failed to replicate study 1.

Table 10
Participants' drinking habits in study 1 and study 2 and results of comparisons for all measures on the TLFB

	Study 1	*Study 2*	*t-score*	*p*
Total Drinks	112.30	95.04	0.79	.429
Binge Days	8.69	5.74	1.36	.181
Drunk Days	9.94	7.04	1.42	.160
Drinking Days	24.49	28.61	-0.99	.328

Note. Drinking habits are self-reported on Timeline Follow-Back as total number in past 90 days. Contrasts done via two-way two-sample t-tests.

Habituation to Alcohol-related Cues

It is possible that the methodological differences between study 1 and study 2 are the reason that no *in vivo* attentional bias was observed in study 2. Because the placebo condition in study 2 is similar to the sober state condition of study 2, it was expected that *in vivo* attentional bias would be observed following placebo. However, because the

placebo testing session of study 2 did not occur at the same time for all participants, the potential for attentional bias to be affected by dose order existed, possibly due to overexposure and habituation to the alcohol stimuli. Although the *in vivo* assessment of attention was identical and performed at the same time as it was in study 1, individuals in study 2 participated in the assessment twice as many times as they did in study 1. Additionally, study 2 utilized the visual dot probe task, which contains alcohol-related stimuli. Simply said, individuals in study 2 were exposed to much more alcohol-related stimuli than participants in study 1.

A driving factor believed to influence the pattern of *in vivo* attentional bias observed in study 1 is habituation to stimuli, particularly the habituation to neutral stimuli. Although alcohol-related stimuli are likely more resilient to the impact of habituation compared to their neutral counterparts, there is little chance that they are entirely immune to it. It is possible that over-exposure to alcohol-related stimuli would result in habituation to alcohol, despite its appetitive qualities. Such over-exposure may have taken place in study 2 given the amount of additional time participants spent on the *in vivo* assessment of attention and the extra exposure to visual dot probe stimuli compared to study 1. Session order in study 2 did not affect attentional bias, as *in vivo* attentional bias was not found in the sober state condition regardless of that order in which that session occurred. This lack of attentional bias could be interpreted as participants having habituated to even the alcohol-related stimuli over the course of increased exposures to alcohol stimuli compared to study 1. Habituation to alcohol stimuli may still have occurred even in earliest placebo sessions because participants were still exposed to at least twice as much alcohol-related stimuli in the familiarization

session of study 2 than they were in the familiarization session of study 1. It is possible that habituation to alcohol-related stimuli occurs due to more time spent exposed to stimuli in addition to being exposed to a greater volume of stimuli.

It is worth emphasizing again that despite efforts to make the placebo condition of study 2 as close to the sober state condition of study 1, the two studies are different. Exposure to alcohol-related stimuli has been noted as one such difference, but another significant difference is that study 2 involved the administration of alcohol. Although the placebo administered produced a 0 mg/100 ml BAC, the potential for a placebo effect is still there. As noted in the methodology, efforts were taken to make participants believe as though the placebo beverage did contain alcohol. There is evidence to suggest that expecting an effect of alcohol, such as when receiving a placebo, can itself lead to changes in performance compared to when no beverage is administered and potentially result in participants trying to compensate for what they believe will be impaired or altered (Fillmore, Carscadden & Vogel-Sprott, 1998; Testa et al., 2006). Attentional bias, however, has been observed under placebo in numerous studies and even in this study appears to be present following placebo and even doses of alcohol that produce less than a BAC of 80 mg/100 ml in the visual dot probe task. Therefore, although a potential placebo effect is worth keeping in mind, it seems probable that the more likely culprit for a lack of attentional bias is a habituation to alcohol-related stimuli due to over-exposure.

Relationship Between Tasks

An additional curiosity of study 2 was the finding that fixation times to alcohol objects in the *in vivo* assessment of attention did not relate to fixation times to alcohol-stimuli on the visual dot probe task. A potential explanation for this would be that there is

simply too much loss of control in the *in vivo* assessment of attention such that participants are not attending to target stimuli in any patterned or consistent way because they have a wide array of other stimuli to attend. By comparison, the visual dot probe task is more restrictive, providing a less stimulus-rich environment. There is an inherent reciprocal nature of the visual dot probe task, where participants only have the option of two stimuli, and attention paid to one is directly at the cost of attention allocated towards the other. Additionally, the tasks utilize different stimuli, which could have an effect on whether or not individuals demonstrate biased attention depending on whether participants find the stimuli to be adequately attention-grabbing. Despite their differences, both tasks demonstrate substantial consistency over the three test sessions with alpha scores of 0.83 for the *in vivo* assessment of attention and 0.86 for the visual dot probe task. This indicates that individuals who strongly attended to alcohol in one testing session continued to do so in all testing sessions on that task and vice-versa. There appears to be systematic responding within both tasks. Essentially, a lack of relationship between the tasks, but consistency within the tasks would suggest that the tasks are measuring two different constructs.

Alcohol Stimuli

Differences in attention allocation between the tasks could be due to the unique stimuli of each task. Although both the *in vivo* assessment of attention and the visual dot probe task feature alcohol-related stimuli paired with neutral beverages, the number and particular type of stimuli are different between the tasks. The visual dot probe task features 10 alcohol and neutral beverage images, whereas the *in vivo* assessment contains 4 alcohol and neutral beverage objects. The visual dot probe task also features a greater

variety of type and containers of alcohol, featuring wine, alcohol in martini glasses and cans of beer, none of which are present in the *in vivo* assessment. It is possible, then, that this particular set of participants found the alcohol-related items of the visual dot probe task to be preferable and therefore more attention grabbing than those they were exposed to in the *in vivo* assessment, resulting in attentional bias to alcohol being only observed in the one task. This version of the visual dot probe task is a frequently used measure of attentional bias that reliably observes the phenomenon (Roberts & Fillmore, 2015; Weafer & Fillmore, 2013). There is therefore evidence to indicate that the stimuli used in the visual dot probe task are reliable in measuring attentional bias, where the same cannot be said for the stimuli of the *in vivo* assessment of attention.

Validity of the Visual Dot Probe Task

Further evidence for the validity of the visual dot probe task in measuring attentional bias comes from the replication of the satiation effect of alcohol consumption on attentional bias and the maintenance of attentional bias to food under the same effects of alcohol. Attentional bias in study 2 was observed to decline in a dose-dependent manner, as participants consumed a higher dose of alcohol, their attentional bias displayed on the visual dot probe task was reduced. This observation is consistent with findings from previous research (Weafer & Fillmore, 2013). As individuals consumed more alcohol, it is likely that they felt less desire to drink and therefore were less drawn towards attending to alcohol-stimuli.

A novel finding in study 2 which suggests the specificity of alcohol consumptions effects on attentional bias and the discriminant validity of the alcohol stimuli used in the visual dot probe task is the consistency of attentional bias to food stimuli regardless of

alcohol consumption. On the food version of the visual dot probe task, food bias was observed in all testing sessions, with no significant reduction in the degree attentional bias to food displayed over the same period of time and following the same doses of alcohol that bias to alcohol waned. This suggests that attentional bias does not appear to be globally reduced by alcohol consumption. In other words, this dissertation provides evidence that alcohol consumption reduces bias only to alcohol-related stimuli, while attentional bias to other appetitive stimuli is maintained. Furthermore, this finding indicates that the alcohol stimuli used in the visual dot probe task are sensitive to the effects of alcohol consumption on bias, lending additional credibility to the validity of those stimuli in measuring attentional bias to alcohol.

Future Directions

An overarching goal of this research was to evaluate existing and identify novel means of assessing attentional bias in the laboratory. Because it has reliably been shown to capture the phenomenon, if any measure used in this research could be considered the criterion for attentional bias to alcohol, it would have to be the visual dot probe task. The novel approach to using eye-tracking glasses as a means to observe *in vivo* attentional bias would then be compared to this criterion. Study 2 demonstrated that findings from the *in vivo* assessment of attention did not relate to observations on the visual dot probe task. What does this mean for the use of eye-tracking glasses in measuring attentional bias? A reliable measure of *in vivo* attentional bias would be the most ecologically valid means of assessing for attentional bias to alcohol. Study 1 demonstrated that *in vivo* attentional bias can be measured using eye-tracking glasses, whereas study 2 failed to

identify and replicate those findings. It is unfortunate that study 2 was unable to replicate the findings of study 1, but likely candidates to explain this discrepancy have been raised.

There are methodological differences between study 1 and study 2, where the participants of study 2 were exposed to much more alcohol-related stimuli throughout the course of testing which may have resulted in habituation to even the alcohol items in the *in vivo* assessment of attention. Differences found between the *in vivo* assessment and the visual dot probe task are also potentially due to the difference in stimuli used or other methodological distinctions that can only be speculated on, such as the longer period of time individuals are exposed to stimuli in the *in vivo* assessment compared to the visual dot probe task. Using the visual dot probe as a criterion for attentional bias, a methodological change for the *in vivo* exposure could be matching stimuli as closely as possible between the two tasks and could result in comparable performance between the two. Taken together, attempting to find ways to assess for *in vivo* attentional bias is still a worthwhile pursuit. It is possible that with methodological changes such as modifying the stimuli and reducing exposure to alcohol-stimuli and thereby reducing habituation, the *in vivo* assessment of attention can demonstrate how attentional bias emerges in the real world.

Conclusions

Attentional bias to alcohol has been the focus of considerable research in the field of alcohol abuse for a number of years. This area of research comes from the incentive salience model, where alcohol-related stimuli have been theorized to activate an automatic process that elicits an individual to begin consumption regardless of whether that was their intention (Stacy & Wiers, 2010). Such automatic responses to alcohol-

related stimuli are likely to result in individuals allocating increased attention to alcohol, thus, an attentional bias to alcohol emerges. The phenomenon is an important one to continue and explore, as attentional bias could be considered a cognitive indicator of heavy drinkers and those with a potential towards alcohol abuse. Additionally, it is theorized that attentional bias may serve a role in motivation for alcohol consumption, where attention given towards alcohol may result in an increased likelihood for initiation of a drinking episode (Ryan, 2002a).

Traditionally, image-display tasks have been the primary means by which attentional bias is observed in the laboratory. Study 1 of this research aimed to utilize a novel, *in vivo* means of observing attentional bias. It was found that attentional bias to alcohol objects emerged in later *in vivo* exposures, likely the result of habituation to other, neutral stimuli. In study 2 no such attentional bias was observed in the *in vivo* task, potentially as a consequence of over-exposure to alcohol-stimuli and thus habituation even to those objects. The visual dot probe task was the only task in study 2 to demonstrate attentional bias and identify changes in attentional bias due to alcohol consumption. Indeed, the evidence for the effect of satiety wherein attentional bias decreases following increasing doses of alcohol in study 2 provides support for the theory that attentional bias may motivate drinking, where bias is strongest in the sober state. This dissertation suggests the possibility that the visual dot probe task is the most reliable and valid task for measuring attentional bias, and this research provided no evidence for shortcomings of the task or a superior approach to observing the phenomenon. The challenge moving forward is determining if there is a way by which attentional bias can be observed outside of a computer screen. For this reason, it is still important to continue

to explore alternative and novel means for observing attentional bias, such as by using eye-tracking glasses and modifying the *in vivo* assessment used in this research, in order to determine if there exist ways to more accurately understand attentional bias outside of the laboratory, an area that continues to be one for which the field can only speculate.

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RESEARCH EXPERIENCE

2012 – Present	**Graduate Student Researcher: Alcohol Research Lab** **University of Kentucky**
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PUBLICATIONS

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