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ATTENTIONAL BIAS AND ALCOHOL ABUSE

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ATTENTIONAL BIAS AND ALCOHOL ABUSE

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

Jessica Jane Weafer

Lexington, Kentucky

Director: Dr. Mark Fillmore, Professor of Psychology

Lexington, Kentucky

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ABSTRACT OF DISSERTATION

ATTENTIONAL BIAS AND ALCOHOL ABUSE

Selective attention towards alcohol-related cues (i.e., "attentional bias") is thought to reflect increased incentive motivational value of alcohol and alcohol cues acquired through a history of heavy alcohol use, and as such attentional bias is considered to be a clinically relevant factor contributing to alcohol use disorders. This dissertation consists of two studies that investigated specific mechanisms through which attentional bias might serve to promote alcohol abuse. Study 1 compared magnitude of attentional bias in heavy (n = 20) and light (n = 20) drinkers following placebo and two doses of alcohol (0.45 g/kg and 0.65 g/kg). Heavy drinkers displayed significantly greater attentional bias than did moderate drinkers following placebo. However, heavy drinkers displayed a dose-dependent decrease in response to alcohol. Individual differences in attentional bias under placebo were associated with both self-reported and laboratory alcohol consumption, yet bias following alcohol administration did not predict either measure of consumption. These findings suggest that attentional bias is strongest before a drinking episode begins, and as such might be most influential in terms of initiation of alcohol consumption. Study 2 addressed theoretical accounts regarding potential reciprocal interactions between attentional bias and inhibitory control that might promote excessive alcohol consumption. Fifty drinkers performed a measure of attentional bias and a novel task that measures the degree to which alcohol-related stimuli can increase behavioral activation and reduce the ability to inhibit inappropriate responses. As hypothesized, inhibitory failures were significantly greater following alcohol images compared to neutral images. Further, heightened attentional bias was associated with greater response activation following alcohol images. These findings suggest that alcohol stimuli serve to disrupt mechanisms of behavioral control, and that heightened attentional bias is associated with greater disruption of control mechanisms following alcohol images. Taken together, these studies provide strong evidence of an association between attentional bias in sober individuals and alcohol consumption, suggesting a pronounced role of attentional bias in initiation of consumption. Further, findings show that attention to alcohol cues can serve to disrupt mechanisms of inhibitory control that might be necessary to regulate drinking behavior, suggesting a potential means through which attentional bias might promote consumption.

KEYWORDS: Attentional Bias, Inhibitory Control, Alcohol, Heavy Drinkers, Behavioral Activation

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ATTENTIONAL BIAS AND ALCOHOL ABUSE

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Chapter 1

INTRODUCTION

Alcohol abuse is an enormous societal problem, both in terms of its acute behaviorally impairing effects on the drinker and in terms of the long-term health problems that occur as a function of prolonged excessive use. The various behavioral and cognitive functions that are impaired in response to excessive alcohol use can lead to immediate negative consequences, including risky sexual behavior, driving while intoxicated, aggressive behavior, and hangover (Marczinski, Grant, & Grant, 2009). Beyond the acute effects, long-term abuse of alcohol is also associated with a host of social, interpersonal, and health-related problems for the drinker, such as lack of employment, neglect of one's family and other loved ones, and increased risk for developing serious chronic illnesses (e.g., liver cirrhosis). Understanding reasons why individuals continue to abuse alcohol (or other drugs), despite the accumulation of such negative consequences, has been a long-standing challenge for researchers. Several theories have been advanced to account for this seemingly self-destructive pattern of drug use. At the crux of many of these accounts is the argument that, for some individuals, the positive rewarding effects of a drug act as powerful reinforcers for the user, such that excessive drug use continues despite the accrual of negative consequences (Koob, 2003; Koob et al., 1998). With respect to alcohol, the argument is that, for some drinkers, the acute rewarding or pleasurable effects that occur during a drinking episode simply outweigh the negative short-term and long-term consequences of excessive use. Thus, excessive use continues despite the growing negative consequences.

In recent years there has been a burgeoning interest in associations between the rewarding effects of alcohol and alcohol-related cues, and consequently the degree to which selective attention directed toward such cues could serve to promote alcohol abuse. Research regarding such an attentional bias (i.e., a preferential focus of attention towards alcohol stimuli) has produced a wealth of evidence suggesting a pronounced attentional bias towards alcohol-related cues in heavy and problematic drinkers. Additionally, initial evidence suggests that magnitude of attentional bias is associated with relapse in alcohol-dependent individuals, and that retraining of attentional bias (away from alcohol cues) can have a positive impact on treatment outcome. As such, gaining a better understanding of the mechanisms through which attentional bias might operate to promote alcohol consumption behavior could have potentially significant contributions to the understanding of alcohol use disorders, including implications for treatment. The aim of this dissertation was to better understand the underlying mechanisms through which attention to alcohol cues serves to promote alcohol abuse.

Attentional Bias towards Alcohol-related Stimuli

Theoretical accounts of the role of attentional bias in substance abuse rely heavily on the incentive sensitization theory of Robinson and Berridge (1993, 2001). The theory is based on evidence that drugs of abuse have the ability to produce long-lasting changes in the organization of brain systems, including those normally involved in the process of incentive motivation and reward (i.e., "wanting" for more drug). Such neuroadaptations cause these systems to become hypersensitive to drug administration, and this is said to be a critical process in addiction. Specifically, initial drug administration comes to elicit a powerful urge or motivation to consume additional amounts of the drug, often resulting in

excessive, uncontrollable drug use. Importantly, over a history of drug use, drug-related cues (e.g., bottle of wine, can of beer) come to be paired with drug consumption through the process of classical conditioning, and as such this same "wanting" system also becomes sensitized to drug-related stimuli. Over time, drug cues alone come to elicit a pronounced motivation for drug consumption. Accordingly, these cues become increasingly meaningful and salient, and therefore "grab the attention" of drug users when they are encountered in the environment. The high incentive-motivational properties of the cues make them especially attractive and wanted, and this cue-induced motivation for consumption is thought to play a pronounced role in promoting use. In terms of alcohol abuse, attentional bias for alcohol-related stimuli is thought to reflect the increased incentive motivational value of alcohol for heavy drinkers and likely facilitates alcohol consumption in problem drinkers (Field & Cox, 2008; Ryan, 2002).

Laboratory Evidence of Attentional Bias towards Alcohol-related Stimuli

Several laboratory tasks have been developed to examine attentional bias towards alcohol-related stimuli, including the alcohol Stroop, flicker change blindness, and visual probe and dot probe tasks. Recent studies have focused on the dot probe and visual probe tasks, in which alcohol-related and matched control pictures are presented side by side on a computer screen for a short period of time (e.g., 50-1000 ms). The stimuli then disappear and a probe (e.g., X) is presented in one of the locations on the screen. Participants are instructed to respond as quickly as possible to the probe by executing a key press on the keyboard. Attentional bias is measured by comparing reaction times when the probe replaces an alcohol-related image to reaction times when the probe replaces a neutral image. Faster reaction times to probes replacing alcohol-related images

are thought to indicate an attentional bias towards those images. This is based on the assumption that participants are faster to respond to probes that appear in the region of visual display to which they are currently attending. In order to directly observe which stimuli are being attended to, eye-monitoring techniques have now been applied to these tasks, allowing for a more direct assessment of attentional focus. Specifically, eye-tracking devices provide a measure of the amount of time spent looking at alcohol versus neutral pictures, as well as the proportion of trials in which the initial gaze is directed towards alcohol images versus neutral images.

The hypothesis that heavy alcohol drinkers develop cognitive biases that facilitate detection and selective processing of alcohol cues (Ryan, 2002) has been tested extensively using these tasks, and results have consistently shown an attentional bias in heavy drinkers compared with light drinkers (Field, Christiansen, Cole, & Goudie, 2007; Jones, Bruce, Livingstone, & Reed, 2006; Murphy & Garavan, 2011; Sharma, Albery, & Cook, 2001; Tibboel, De Houwer, & Field, 2010; Townshend & Duka, 2001). Further, individual difference analyses have shown that magnitude of attentional bias predicts level of consumption and alcohol problem severity in social drinkers (Ceballos, Komogortsev, & Turner, 2009; Fadardi & Cox, 2008; Miller & Fillmore, 2010; Murphy & Garavan, 2011) and alcoholics (Jones et al., 2006). Importantly, attentional bias also has been shown to predict relapse in alcohol dependent individuals. Garland et al. (in press) found that magnitude of attentional bias following 10 weeks of treatment significantly predicted occurrence and timing of relapse, even after controlling for pre-treatment level of alcohol dependence severity. Taken together, these studies provide

important evidence in support of an association between increased attention to alcohol cues and problematic alcohol consumption.

Alcohol Abuse and Attentional Bias

Theoretical accounts of attentional bias suggest that heavy drinkers should not only display a bias towards alcohol stimuli, but that attention directed towards such stimuli should increase motivation to seek out and consume alcohol, thus directly contributing to drinking behavior (Field & Cox, 2008; Franken, 2003). Researchers are beginning to examine this predicted relationship between attentional bias and alcohol consumption in the laboratory. For instance, Field and Eastwood (2005) manipulated attentional bias in heavy social drinkers by having participants complete an attentional training session on a modified visual probe task. Half of participants were trained to attend to alcohol pictures (i.e., the probe replaced alcohol pictures on 100% of trials), and half were trained to avoid alcohol pictures (i.e., the probe replaced neutral pictures on 100% of trials). After the training procedure, those trained to attend to alcohol images displayed a significantly greater attentional bias than did those trained to avoid alcohol. Moreover, those in the attend alcohol group consumed significantly more beer than did those in the avoid alcohol group on a taste-test following the attentional training, suggesting an influential role of attentional bias on amount of alcohol consumption. Two additional studies similarly reported successful retraining of attentional bias using modified visual probe procedures; however, neither of these studies showed significant generalization of attentional retraining when attentional bias was tested using different tasks or different alcohol stimuli (Field et al., 2007; Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007).

More long-lasting effects of attentional retraining have also been examined. Fadardi and Cox (2009) administered the Alcohol Attention-Control Training Program (AACTP), designed to decrease levels of attentional bias towards personally relevant alcohol-related stimuli, to a group of heavy drinkers. The authors reported a significant reduction in attentional bias following the AACTP that was maintained at a 3-month follow-up. Moreover, alcohol consumption was significantly reduced at the 3-month follow-up as well. Similarly, Schoenmakers et al. (2010) showed that attentional retraining can facilitate treatment completion in abstinent alcoholics, as well as delay time to relapse. Taken together, these findings provide initial support for the causal role of such a bias in promoting alcohol consumption.

Attentional Bias Following Alcohol Consumption

The majority of research to date has focused on assessing attentional bias in sober individuals; however, it is also important to understand if attentional bias is heightened in intoxicated individuals, and if this potential increase might serve to promote ongoing, excessive consumption once a drinking episode has been initiated. According to Robinson and Berridge (1993) acute alcohol consumption should serve to engage the "wanting" pathway, increasing motivation for additional consumption. Drug-induced activation of this pathway could also increase attention to alcohol cues, due to conditioned associations between alcohol cues, alcohol reward, and the incentive-motivation neural pathway. Heightened attentional bias could then in turn serve to further potentiate motivation for ongoing consumption, resulting in a perpetuating cycle of increased motivation and consumption. To date, only a small number of studies have investigated alcohol effects on attentional bias, and results provide initial support for an

increase (Duka & Townshend, 2004; Schoenmakers, Wiers, & Field, 2008) or persistence (Miller & Fillmore, 2011) in bias under alcohol. However, no studies have examined how alcohol effects on attentional bias might differ for heavy and light drinkers. As individuals with a history of heavy alcohol consumption should display a more highly sensitized incentive-motivational response to the drug and drug cues (Robinson & Berridge, 1993), these drinkers might be expected to show a more pronounced alcohol-induced increase in attentional bias, and subsequent increase in motivation for further consumption.

Attentional Bias and Behavioral Control

A related aspect of attentional bias that is poorly understood concerns the specific means through which attentional biases might operate to promote problematic alcohol consumption. One possibility is through disruption of behavioral control, as proposed by several researchers who emphasize the importance of both increased incentive-motivational properties of alcohol-related stimuli and impaired inhibitory control in drug abuse (Dawe, Gullo, & Loxton, 2004; Robinson & Berridge, 1993). According to this rationale, increased incentive value of drugs (and drug cues) and decreased levels of inhibitory control work in conjunction and possibly interactively to increase the likelihood of unregulated drug-seeking and prolonged drug-taking behavior. There is much neuroanatomical evidence in support of the association between inhibitory control and attentional bias, as well as the combined role of the two mechanisms in abusive drug-taking behavior. The majority of this research points toward the importance of dopamine activity, particularly within mesolimbic and mesocortical pathways (Goldstein & Volkow, 2002; Lyvers, 2000). The mesolimbic circuit, including the nucleus accumbens,

amygdala, and hippocampus, is associated with rewarding effects of drugs of abuse and drug-related cues, and the mesocortical circuit, including the prefrontal, orbitofrontal, and anterior cingulate cortex, is implicated in behavioral control, including response inhibition. As these circuits are hypothesized to work both in parallel and interactively (Goldstein & Volkow, 2002), any cue-induced increase in activation of reward circuits could simultaneously disrupt inhibitory mechanisms necessary to restrain from engaging in consumption. As such, it has been proposed that attentional bias for alcohol-related cues could directly influence an individual's ability to control impulses to consume the drug. Although intriguing, little experimental research has addressed this hypothesis.

Proposed Studies

The purpose of this dissertation was to investigate two specific mechanisms through which attentional bias might serve to promote alcohol abuse. The first study examined the direct effect of alcohol on attentional bias in heavy and light drinkers, as well as the degree to which magnitude of attentional bias predicted self-reported and ad lib alcohol consumption. The second study addressed the possibility that attention to alcohol cues could serve to directly influence behavior, possibly by disrupting mechanisms of behavioral control.

Chapter 2

ACUTE ALCOHOL EFFECTS ON ATTENTIONAL BIAS IN HEAVY AND MODERATE DRINKERS

(STUDY 1; Weafer & Fillmore)

Introduction

Binge drinking is highly prevalent among young adults, with almost half of college students reporting binge drinking in epidemiological studies (Marczinski et al., 2009). Binge drinking is associated with numerous negative consequences, including unsafe sexual activity, assault, injury, and automobile accidents (Flowers et al., 2008; Presley & Pimentel, 2006; Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994; Wechsler, Dowdall, Davenport, & Castillo, 1995; Wechsler & Nelson, 2001). As such, understanding personal characteristics that lead certain individuals to binge drink has been of long-standing interest. For the most part, this research has focused on relatively stable factors that might predispose an individual to heavy alcohol use, such as personality traits or genetic make-up (e.g., Dick & Bierut, 2006; Sher, Grekin, & Williams, 2005). However, in recent years there has been a burgeoning interest in how acute effects of alcohol itself might serve to promote binge drinking. For instance, studies have shown that binge and non-binge drinkers differ in terms of their subjective and behavioral responses to alcohol, with binge drinkers experiencing more stimulation and displaying greater disinhibiting effects from alcohol (Fillmore, 2003, 2007; Holdstock, King, & de Wit, 2000; Marczinski, Combs, & Fillmore, 2007; Quinn & Fromme, 2011; Rose & Grunsell, 2008; Weafer & Fillmore, 2008). Such increased stimulation and

disinhibition from alcohol could be important factors contributing to excessive consumption in binge drinkers.

Another means by which the acute effects of alcohol could promote binge drinking involves the ability of the drug to increase the drinker's selective attention to alcohol-related cues in the drinking situation (e.g., Field & Cox, 2008; Field, Wiers, Christiansen, Fillmore, & Verster, 2010). Theoretical accounts highlighting the importance of such an "attentional bias" rely heavily on the incentive sensitization theory of Robinson and Berridge (1993, 2001). The theory posits that drugs of abuse have the ability to produce neuroadaptations in incentive motivation and reward systems, causing these systems to become hypersensitive to both drugs and drug-related stimuli. Over a prolonged period of use, substance-related cues come to be associated with drug consumption and the ensuing incentive-motivational and rewarding effects of the drug through classical conditioning. As a result, drug-related stimuli become increasingly salient for users, receiving greater attention when they are encountered in the environment. Moreover, drug-related cues take on high incentive-motivational properties themselves, eliciting increased motivation for drug-seeking and drug-taking. In terms of alcohol abuse, attentional bias is thought to reflect increased incentive motivational value of alcohol acquired through a history of heavy alcohol use (Field & Cox, 2008; Ryan, 2002). As such, alcohol cues themselves come to elicit motivation to consume alcohol. For this reason, evidence of attentional bias to such cues might be of clinical significance because of its potential to contribute to abusive patterns of consumption and ultimately to alcohol dependence.

Attentional bias has been studied extensively in sober individuals, and findings provide consistent evidence for greater attentional bias in heavy drinkers compared with light drinkers (Field, Christiansen, et al., 2007; Murphy & Garavan, 2011; Sharma et al., 2001; Tibboel et al., 2010; Townshend & Duka, 2001). Attentional bias also predicts individual differences in level of consumption and alcohol problem severity in both social drinkers (Ceballos et al., 2009; Fadardi & Cox, 2008; Miller & Fillmore, 2010; Murphy & Garavan, 2011) and alcoholics (Jones et al., 2006). There is also some emerging experimental evidence in support of a causal role of attentional bias in alcohol consumption. For instance, studies have shown that attentional biases can be manipulated through a retraining procedure, and this retraining can influence subsequent alcohol consumption. Specifically, individuals trained to attend to or approach alcohol cues showed an increase in attentional bias as well as greater alcohol consumption in a taste-rating task, compared to those trained to avoid alcohol stimuli (Field & Eastwood, 2005; Wiers, Rinck, Kordts, Houben, & Strack, 2010). Such effects of training might persist for some time. Fadardi and Cox (2009) administered a training program designed to decrease levels of attentional bias towards alcohol-related stimuli and reported a significant reduction in drinkers' attentional bias and alcohol consumption following training that was maintained over a 3-month follow-up. Similar effects of retraining attentional bias have been reported by others as well (Schoenmakers et al., 2010). Taken together, these findings provide some initial support for the causal role of such a bias in promoting alcohol consumption.

Although there are numerous studies showing that attentional bias is associated with heavy alcohol consumption, less is known about how a drinker's attentional bias

might be altered once they begin to consume alcohol during a drinking episode. Some initial studies suggest that attentional bias might be increased following consumption of a low dose of alcohol (0.3 g/kg) (Duka & Townshend, 2004; Schoenmakers et al., 2008). However, neither of these studies observed any significant attentional bias when subjects were sober (i.e., following placebo). Duka and Townshend (2004) also failed to observe an increase in attentional bias following a higher dose of alcohol (0.6 g/kg). Our group reported significant attentional bias under placebo and two active doses of alcohol (0.32 g/kg and 0.64 g/kg), yet the magnitude of the bias was unaffected by the drug (Miller & Fillmore, 2011).

Although these findings provide some initial support of a possible increase of attentional bias following a low alcohol dose and for the possible occurrence of attentional bias at higher doses, the evidence is limited. Also, studies of alcohol effects on attentional bias have not considered the drinking habits of the individuals being tested. The drinking habits of the individuals could be important in determining how alcohol might affect their attentional bias. According to the incentive sensitization theory, heavy drinkers should be sensitized to the incentive-motivational effects of alcohol and alcohol cues. As such, it is reasonable to assume that any increase in attentional bias following alcohol consumption would be more pronounced in these individuals (Robinson & Berridge, 1993; Field et al., 2010). By contrast, more moderate drinkers have had less opportunity to acquire incentive-motivational responses to alcohol cues, and consequently should display less attentional bias to alcohol cues both prior to and following alcohol consumption.

This study sought to examine the degree to which acute effects of alcohol on attentional bias might differ based on the drinkers' history of prior alcohol use. Specifically, I chose to focus on frequency of binge drinking as the primary index of drinking history, as frequent binge drinkers typically consume much greater quantities of alcohol than infrequent drinkers (White, Kraus, & Swartzwelder, 2006). Participants were classified as heavy drinkers (i.e., individuals who frequently binge drink) or moderate drinkers (i.e., individuals who rarely or never binge drink) based on retrospective reports of daily alcohol consumption over the past 12 weeks. Attentional bias was assessed in response to placebo and two active doses of alcohol (0.45 g/kg and 0.65 g/kg). It was hypothesized that heavy drinkers would show a greater attentional bias compared to moderate drinkers in response to placebo, and that alcohol would increase attentional bias specifically in the heavy drinkers. Further, I examined the extent to which individual differences in attentional bias predicted alcohol self-administration, as measured by both self-report and laboratory ad lib consumption. Individuals who displayed a heightened attentional bias were expected to consume more alcohol on both measures.

Methods

Participants

Volunteers were recruited to participate in a study of alcohol effects on computer tasks via notices placed on community bulletin boards and by university newspaper advertisements. Forty adults (18 women and 22 men) aged 21 to 29 (mean age = 23.4, *SD* = 2.6) participated in this study. Screening measures were conducted to determine medical history and current and past drug and alcohol use. Any volunteers who self-reported head trauma, psychiatric disorder, substance abuse disorder, or alcohol

dependence, as determined by a score of 5 or higher on the Short-Michigan Alcoholism Screening Test (S-MAST; Selzer, Vinokur, & van Rooijen, 1975), were excluded from participation. The University of Kentucky Medical Institutional Review Board approved the study, and participants received $160.

Materials and Measures

Visual Probe Task. Attentional bias was measured by a visual probe task used in previous research (Miller & Fillmore, 2010, 2011). The task was operated using E-Prime experiment generation software (Psychology Software Tools, Pittsburgh, PA) and was performed on a PC. The participant's head was fixed in position using a chin rest and eye movements were recorded using a Model 504 Eye Tracking System (Applied Science Laboratory, Boston MA). Eye locations were sampled at 60 Hz and given X-Y coordinates used to determine fixations. Fixations were identified by gazes with standard deviations less than 0.5 degrees of visual angle for durations of 100 msec or longer.

A trial consisted of the presentation of two pictures (alcohol and neutral images) for 1000 ms. Upon offset of the picture pair, a target probe (X) appeared on either the left or right side of the screen, in the same location as one of the previously presented images. Participants were instructed to look at the pictures while they were on the screen, and to respond as soon as the probe was presented by pressing one of two response keys on the keyboard indicating on which side the probe appeared. The probe response was included in order to provide participants with motivation to look at the pictures for the duration of their presentation on the screen (i.e., until the target probe appeared). Critical task stimuli consisted of ten pairs of matched alcohol-related and neutral (i.e., non-alcohol-related) images. Alcohol images depicted a solitary image of an alcoholic beverage. Each of these

images was matched with a corresponding neutral image consisting of a non-alcohol drink (e.g., a can of beer matched with a can of soda). The 10 image pairs were presented four times each, once for each of the four possible picture/target combinations (i.e., left and right picture location and left and right target probe location) for a total of 40 critical test trials. Forty filler trials consisting of neutral image-only pairs were randomly intermixed with the 40 critical trials. Attentional bias was measured by comparing mean fixation time (ms) on alcohol-related images to mean fixation time (ms) on neutral images across the 40 critical test trials, and an attentional bias score was calculated by subtracting mean fixation time on neutral images from mean fixation time on alcohol-related images. Previous research has shown that this is a sensitive measure of attentional bias (Miller & Fillmore, 2010, 2011). A test required five min to complete.

Desire for Alcohol. Self-reported ratings of desire for alcohol were measured on a visual analogue scale that has been used in previous research (e.g., Fillmore & Blackburn, 2002). Participants placed a vertical line representing the degree to which they "desire more alcohol" on a 100 mm scale ranging from 0 mm "not at all" to 100 mm "very much".

Time Line Follow-Back (TLFB; Sobell & Sobell, 1992). Participants completed a retrospective time line calendar of their alcohol consumption for the past 12 weeks to assess daily patterns of drinking. The measure uses "anchor points" to structure and facilitate participants' recall of past drinking episodes. For each day, participants estimated the number of standard drinks they consumed and the number of hours they spent drinking. This information, along with gender and body weight, was used to estimate the resultant blood alcohol concentration (BAC) obtained for each drinking day

using well-established, valid anthropometric-based BAC estimation formulae that assume an average clearance rate of 15 mg/100 ml per hour (McKim, 2007; Watson, Watson, & Batt, 1981). These formulae have been used in previous studies and have been shown to yield high correlations with actual resultant BACs obtained under laboratory conditions (Fillmore, 2001). Days in which the estimated resultant BAC was 80 mg/100 ml or higher were classified as binge days (NIAAA, 2004). The TLFB provided four measures of drinking habits over the past 12 weeks: (a) binge days (total number of binge episodes); (b) drunk days (total number of days on which participants reported feeling drunk); (c) drinking days (total number of days alcohol was consumed); (d) total drinks (total number of drinks consumed).

Procedure

Telephone Screen. Interested volunteers called the laboratory to participate in a screening interview conducted by a research assistant. Because the study involved an ad lib beer consumption session, only volunteers who reported liking beer were eligible for participation. Volunteers were pre-screened in terms of typical drinking habits to select for 20 heavy and 20 moderate drinkers (male and female), based on weekly frequency of binge drinking. All volunteers were asked to estimate the number of drinks typically consumed per occasion, as well as the typical hourly duration of a drinking occasion. Using the formulae described above (McKim, 2007; Watson et al., 1981), the resultant BAC typically obtained was calculated for each volunteer. Those with a resultant BAC of 80 mg/100 ml or greater were considered potentially eligible for the heavy drinker group. Those with a resultant BAC of less than 80 mg/100 ml were considered potentially eligible for the moderate drinker group.

Intake Session. All participants completed an intake session to verify their classification as either a heavy or moderate drinker, based on frequency of binge episodes in the past 12 weeks as reported on the TLFB. Participants who reported binge drinking on more than a weekly basis were retained in the heavy drinker group. Those who reported binge drinking on less than a weekly basis were retained in the moderate drinker group. Once 20 participants were recruited in each group, recruitment was discontinued. Participants also became acquainted with laboratory procedures during the intake session. Informed consent for participation was provided, height and weight were measured, demographic measures were completed, and a practice test was performed to become familiar with the visual probe task and the eye-tracking equipment.

Dose-Challenge Sessions. All sessions were conducted in the Behavioral Pharmacology Laboratory and testing began between 10 a.m. and 6 p.m. All participants were tested individually. Sessions were scheduled at least 24 hours apart and were completed within four weeks. Participants were instructed to fast for four hours prior to each session, and to refrain from consuming alcohol or any psychoactive drugs for 24 hours. Prior to each session, participants provided urine samples that were tested for drug metabolites, including amphetamine, barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol (ON trak TesTstiks, Roche Diagnostics Corporation, Indianapolis, IN, USA) and, in women, HCG, in order to verify that they were not pregnant (Mainline Confirms HGL, Mainline Technology, Ann Arbor, MI, USA). Breath samples were measured by an Intoxilyzer, Model 400 (CMI, Inc., Owensboro, KY) to verify a zero BAC.

Performance was tested under three doses of alcohol: 0.0 g/kg (placebo), 0.45 g/kg, and 0.65 g/kg. Doses were reduced to 87% for women to achieve equivalent BACs for men and women (Fillmore, 2001; Mulvihill, Skilling, & Vogel-Sprott, 1997). Each dose was administered on a separate test session, and dose order was counterbalanced across groups. Sessions were separated by a minimum of one day and a maximum of one week. The 0.45 g/kg dose produces an average peak BAC of 60 mg/100 ml, and the 0.65 g/kg dose produces an average peak BAC of 80 mg/100 ml. These doses allow for examination of attentional bias at BACs near (i.e., 60 mg/100 ml) and at (i.e., 80 mg/100 ml) the threshold for a binge episode (NIAAA, 2004). These doses were chosen to provide information regarding how attentional bias might function once BACs are substantially elevated. The alcohol beverage was served as one part alcohol and three parts carbonated mix, and was consumed in six min. The placebo beverage consisted of four parts carbonated mix and was served in the same manner. Alcohol (3 ml) was floated on top, and the glass was sprayed with an alcoholic mist, which resembled condensation and provided a strong alcoholic odor. Previous research has shown that individuals report that this beverage contains alcohol (e.g., Fillmore & Blackburn, 2002).

Participants' visual probe performance was tested 25 min after drinking began, and ratings of desire for alcohol were obtained 30 min after drinking began. Breath samples were collected at 23 and 35 min after drinking during both the placebo and alcohol test sessions. Once testing was finished, participants remained at leisure in the lounge area until their BACs reached 20 mg/100 ml or below.

Ad Libitum Consumption. The final session measured the participants' ad lib alcohol consumption. Participants completed a taste-rating task (Marlatt, Demming, &

Reid, 1973), which previous research has shown provides a reliable and valid measure of ad lib consumption (Collins, Gollnisch, & Izzo, 1996; Marczinski, Bryant, & Fillmore, 2005; Weafer & Fillmore, 2008). Participants sampled six beers and rated them on various qualities (e.g., aftertaste, fullness), ostensibly to provide information on people's beer preferences. The beers were served in clear, frosted glasses. The beers sampled were Michelob Light™, Rolling Rock™, Sam Adams Light™, Harp™, Coors Light™, and Bud Light™. These were chosen because they are representative of beers commonly consumed by young adults and because they are all similar in per volume alcohol content (4.3, 4.6, 4.3, 4.6, 4.2, and 4.2%, respectively).

Participants were told the session would last six hours, and the tasting portion would last 90 minutes. They were allowed to drink as much or as little of each beer as they liked, but were encouraged to sample enough of each beer to give an accurate rating. The session took place in a room designed to promote a relaxing, leisurely atmosphere. Participants were seated in a large recliner and were provided with a mini-refrigerator to keep the beers cold when they were not being sampled. A DVD player and stereo were also available to provide entertainment. Ad lib sessions were held individually for each participant, and all sessions began at 4 pm. Once the 90 minutes had passed, participants' BACs were measured. The remaining beer was measured in ml and subtracted from the total amount of beer presented to determine the amount of beer consumed by the participant. As with the dose-challenge sessions, participants remained at leisure in the lounge area until their BACs reached 20 mg/100 ml or below.

Criterion Measures and Data Analyses

Attentional Bias. Mean fixation times on alcohol-related and neutral images were analyzed by a 2 (group: heavy drinkers vs. moderate drinkers) X 2 (image: alcohol vs. neutral) X 3 (dose: 0.0 g/kg, 0.45 g/kg, and 0.65 g/kg) mixed-design analysis of variance (ANOVA) in which group was the between-subjects factor and image and dose were within-subjects factors. Gender was initially entered as a covariate. No main effect or interactions involving gender were found, and as such analyses reported in the results were collapsed across gender.

Desire for Alcohol. Group and dose effects on self-reported desire for alcohol were analyzed by a 2 (group) X 3 (dose) ANOVA with group as the between-subjects factor and dose as the within-subjects factor, and gender as a covariate. No main effect or interactions involving gender were found, and as such analyses reported in the results were collapsed across gender.

Ad Lib Alcohol Consumption. The principal measure of ad lib consumption was the amount of beer (ml) consumed by the participant. The weight-adjusted dose of alcohol consumed was also calculated (total amount of alcohol consumed divided by participant's body weight), and ad lib BAC was measured. Group differences in measures of ad lib consumption were analyzed by between-groups *t* tests (heavy vs. moderate drinkers).

Attentional Bias and Desire for Alcohol as Predictors of Alcohol Consumption. Bivariate correlational analyses were conducted to examine the degree to which individual differences in attentional bias scores and desire for alcohol ratings predicted measures of ad lib and self-reported alcohol consumption within the entire sample.

Results

Drinking Habits and Demographics

Table 2.1 presents drinking habit and demographic information for the 20 heavy drinkers (8 women and 12 men) and the 20 moderate drinkers (10 women and 10 men). The table shows pronounced group differences in alcohol consumption, providing further confirmation of the validity of my selection criteria. Compared with moderate drinkers, heavy drinkers had more binge episodes, $t(38) = 12.9$, $p < .001$, $d = 4.1$, felt drunk on more days, $t(38) = 6.8$, $p < .001$, $d = 2.2$, drank alcohol on more days, $t(38) = 3.8$, $p < .001$, $d = 1.2$, and consumed a larger total number of drinks over the period, $t(38) = 7.2$, $p < .001$, $d = 2.3$.

Dose-Challenge Sessions

Blood Alcohol Concentrations. No detectable BACs were observed under the placebo condition. Group differences in BAC under the active dose conditions were examined by a 2 (group) X 2 (time) X 2 (dose) mixed-design ANOVA. No main effects or interactions involving group were observed, *p*s > .45. There was a main effect of time owing to the rise of BAC over the ascending limb of the BAC curve when testing occurred, $F(1, 38) = 154.8$, $p < .001$, partial $\eta^2 = .80$, and a main effect of dose owing to higher BACs following the 0.65 g/kg dose $F(1, 38) = 50.8$, $p < .001$, partial $\eta^2 = .57$. There was also a time X dose interaction, owing to a steeper rate of rise in BAC following the 0.65 g/kg dose, $F(1, 38) = 6.7$, $p = .01$, partial $\eta^2 = .15$. Mean BACs at pre and posttest under the 0.45 g/kg dose were 48.3 (*SD* = 13.8) mg/100 ml and 58.4 (*SD* = 13.7) mg/100 ml, respectively. For the 0.65 g/kg dose, the mean BACs at pre and posttest were 65.3 (*SD* = 15.0) mg/100 ml and 79.7 (*SD* = 16.8) mg/100 ml, respectively.

Attentional Bias. Due to computer malfunction, I was unable to record eye-movement data for one moderate drinker in response to the 0.45 g/kg dose of alcohol, and as such that participant was removed from dose-effect analyses. A 2 (group) X 2 (image) X 3 (dose) ANOVA of mean fixation times revealed significant main effects of image, $F(1, 37) = 26.6$, $p < .001$, partial $\eta^2 = .42$, and dose, $F(2, 74) = 11.9$, $p < .001$, partial $\eta^2 = .24$, and there was a trend toward a group X image X dose interaction, $F(2, 74) = 2.6$, $p = .08$, partial $\eta^2 = .07$. Table 2.2 presents mean fixation times on alcohol-related and neutral images. The table shows that the main effect of image is due to the overall greater fixation time on alcohol-related compared to neutral images, observed in both drinker groups. Additionally, the main effect of dose is due to the overall decrease in fixation time in response to alcohol, observed in both groups and for both image types.

For ease of presentation and interpretation, magnitude of attentional bias was calculated as a single score. This was done by subtracting mean fixation time on neutral images from mean fixation time on alcohol-related images, such that greater values indicated a greater attentional bias. Magnitude of attentional bias scores are presented in Figure 2.1. One-sample *t* tests were conducted for each attentional bias score to test if the bias was significantly greater than zero. Results showed a significant attentional bias in heavy drinkers in all three dose conditions: placebo, $t(19) = 5.7$, $p < .001$, $d = 1.3$; 0.45 g/kg, $t(19) = 3.1$, $p < .01$, $d = .69$; and 0.65 g/kg, $t(19) = 2.5$, $p = .02$, $d = .56$. By contrast, moderate drinkers displayed a small attentional bias that was not significant at the alpha = .05 level in any dose condition: placebo, $t(18) = 2.0$, $p = .06$, $d = .47$; 0.45 g/kg, $t(18) = 1.2$, $p = .23$, $d = .28$; and 0.65 g/kg, $t(18) = 2.0$, $p = .06$, $d = .46$.

Based on a priori hypotheses regarding group differences in the effects of alcohol on attentional bias, dose effects on these scores were analyzed for each group separately. A one-way repeated-measures ANOVA revealed a significant main effect of dose in heavy drinkers, $F(2, 38) = 4.0$, $p = .02$, partial $\eta^2 = .17$. Figure 2.1 shows that this is due to a dose-dependent *decrease* in attentional bias in this group. Follow-up paired-samples *t* tests comparing attentional bias in the placebo condition to both active doses showed an alcohol-induced decrease in bias that was statistically significant following the 0.65 g/kg dose, $t(19) = 3.0$, $p < .01$, $d = .81$, but not the 0.45 g/kg dose, $t(19) = 1.8$, $p = .09$, $d = .40$. By contrast, a one-way repeated-measures ANOVA revealed no main effect of dose in moderate drinkers, $p = .75$. Between-groups *t* tests compared the attentional bias of heavy versus moderate drinkers following each dose. Heavy drinkers displayed significantly greater bias than moderate drinkers following placebo, $t(37) = 3.0$, $p < .01$, $d = .83$. By contrast, heavy and moderate drinkers did not differ in magnitude of attentional bias in response to either 0.45 g/kg or 0.65 g/kg of alcohol (*p*s > .41).

Desire for Alcohol. Analysis of desire for alcohol ratings revealed a significant main effect of dose, $F(2, 76) = 10.8$, $p < .001$, partial $\eta^2 = .22$. There was no main effect or interaction involving group, *p*s > .36. Figure 2.2 presents mean ratings of desire for alcohol. The figure shows that alcohol increased desire relative to placebo in both heavy and moderate drinkers.

Ad Lib Consumption

Two participants (one heavy drinker and one moderate drinker) were unable to attend the final session of the study due to personal reasons, and therefore I do not have ad lib consumption data available for these participants. There was a considerable range

in consumption across the sample, with individual amounts ranging from 95 to 2120 ml of beer. The weight-adjusted dose consumed ranged from 1.3 to 29.7 mg/kg, and BACs obtained at the end of the 90 minute tasting session ranged from 0 to 120 mg/100 ml. Table 2.3 presents the mean measures of ad lib consumption for heavy and moderate drinkers. Heavy drinkers consumed significantly more alcohol than did moderate drinkers as measured by total ml of beer consumed, $t(36) = 3.6$, $p < .01$, $d = .94$, weight-adjusted dose of alcohol consumed, $t(36) = 3.4$, $p < .01$, $d = .92$, and BAC obtained, $t(36) = 3.1$, $p < .01$, $d = .86$.

Attentional Bias as a Predictor of Alcohol Consumption

Ad Lib Consumption. Bivariate correlational analyses were conducted in the sample as a whole to examine the degree to which individual differences in attentional bias predicted ad lib alcohol consumption, and these correlations are presented in Table 2.4. Results showed that greater attentional bias in response to placebo significantly predicted greater amounts of ad lib consumption, as measured by total ml of beer consumed and weight-adjusted dose consumed (*p*s < .05). There was a trend toward a significant association between attentional bias in response to placebo and BAC obtained at the end of the 90 min drinking session ($p = .06$). By contrast, attentional bias following 0.45 g/kg and 0.65 g/kg alcohol did not predict any ad lib consumption measures (*p*s > .20).

Self-reported Drinking Habits. Bivariate correlational analyses were also conducted to examine the degree to which attentional bias under each alcohol dose predicted self-reported alcohol consumption on the TLFB, and these correlations are also presented in Table 2.4. As the table shows, greater attentional bias under placebo

significantly predicted greater levels of alcohol consumption in terms of number of binge days, "drunk days", drinking days, and total drinks consumed (*p*s < .03). Moreover, as with ad lib consumption measures, no significant associations were found between drinking habits and attentional bias following either active dose (*p*s > .26).

Desire for Alcohol as a Predictor of Alcohol Consumption

Ad Lib Consumption. Bivariate correlational analyses of associations between ratings of desire for alcohol and ad lib alcohol consumption are presented in Table 2.5. The table shows that ratings of desire for alcohol following placebo did not predict any measure of ad lib consumption (*p*s > .69). By contrast, higher ratings of desire for alcohol following both active doses of alcohol predicted greater consumption on each measure of ad lib consumption (*p*s < .05).

Self-reported Drinking Habits. Bivariate correlational analyses of the degree to which desire for alcohol predicted self-reported alcohol consumption on the TLFB are also presented in Table 2.5. As the table shows, desire for alcohol following placebo did not predict any drinking habit measures on the TLFB (*p*s > .39). By contrast, higher desire ratings following the 0.45 g/kg dose predicted a greater number of "drunk days", drinking days, and total drinks (*p*s < .04), and higher desire ratings under the 0.65 g/kg dose predicted a greater number of binge days, "drunk days", and total drinks (*p*s < .03).

Discussion

The current study investigated acute alcohol effects on attentional bias in a group of heavy drinkers and in a comparison group of moderate drinkers. It was hypothesized that heavy drinkers would show a heightened attentional bias to alcohol-related stimuli compared to moderate drinkers, and that acute alcohol administration would serve to

further increase this attentional bias in heavy drinkers. As hypothesized, heavy drinkers displayed a pronounced attentional bias compared to moderate drinkers following placebo. Indeed, the mean score of heavy drinkers was over three times greater than that of moderate drinkers. Moderate drinkers displayed a small magnitude of attentional bias (i.e., not significantly greater than zero at the alpha = .05 level) that remained consistent across each of the alcohol doses. However, contrary to hypothesis, heavy drinkers displayed a dose-dependent *decrease* in attentional bias in response to alcohol. As such, the pronounced group difference observed under placebo was attenuated such that heavy and moderate drinkers did not significantly differ in magnitude of bias under either active dose of alcohol. The study also examined the degree to which individual differences in attentional bias predicted alcohol consumption, measured by self-report and by ad lib consumption within the laboratory. As predicted, there were associations between attentional bias following placebo and measures of self-reported and ad lib alcohol consumption. Specifically, individuals displaying greater attentional bias also self-reported greater alcohol consumption and consumed more alcohol when given ad lib access. However, these robust associations were no longer evident when attentional bias was measured under alcohol. That is, attentional bias towards alcohol-related stimuli following alcohol consumption bore no relation to individuals' self-reported or ad lib alcohol consumption. In sum, the findings indicate heavy drinking behavior is associated with greater magnitude of attentional bias, but only when attentional bias is measured in the sober state (i.e., following placebo) and not after drinking has begun.

The current results replicate previous studies that have demonstrated greater attentional bias in heavy drinkers compared to light drinkers (Field, Christiansen, et al.,

2007; Murphy & Garavan, 2011; Sharma et al., 2001; Tibboel et al., 2010; Townshend & Duka, 2001). Moreover, this is one of the first studies to demonstrate strong associations between individual differences in attentional bias and multiple measures of both self-reported and laboratory ad lib consumption. Specifically, I showed that greater magnitude of attentional bias predicted both frequency and quantity of drinking on a detailed self-report measure of alcohol consumption. Further, I found that attentional bias predicted individual differences in a laboratory measure of ad lib drinking as well. Previous studies using the ad lib consumption task have demonstrated the validity of this task as a measure of consumption patterns outside of the laboratory, suggesting that individual differences in amounts of consumption on this task can be interpreted as possible indicators for abuse potential (Collins et al., 1996; Marczinski et al., 2005; Weafer & Fillmore, 2008). As such, these robust associations between attentional bias in the sober state and measures of alcohol consumption provide additional support for the significance of attentional bias in alcohol abuse. Although no causal inferences can be drawn from these associations, the finding that individuals with greater attentional bias drink most frequently and consume the heaviest quantities of alcohol are in line with the hypothesis that greater attention to alcohol cues (in a sober state) could promote increased consumption, perhaps through increasing the likelihood of initiation of a drinking episode.

To my knowledge, this is the first laboratory study to show an alcohol-induced decrease in attentional bias in heavy drinkers. I originally hypothesized that heavy drinkers would show an increase in attentional bias due to a sensitized incentive-motivational response to alcohol; however, the current findings did not support this hypothesis. One possible explanation for this finding is that the interoceptive cues

following consumption of the active doses (i.e., rewarding effects of the drug) might have surmounted any of the incentive salience normally associated with the alcohol-related stimuli (i.e., alcohol images) when the participant is in the sober state. Theoretical accounts suggest that alcohol-related cues take on a heightened salience for heavy drinkers due to conditioned associations that develop between the cues and the rewarding effects of acute alcohol intoxication (Field & Cox, 2008; Robinson & Berridge, 1993). However, once alcohol consumption is initiated, and the rewarding effects of the active drug are experienced, the drinker's attentional focus on the external alcohol-related signals in the environment (i.e., alcohol pictures) likely diminishes as the incentive salience of these environmental signals cannot compete with the actual interoceptive/subjective rewarding effects of the drug after it is consumed. Such an account would explain the dose-dependent decrease in attentional bias, in that as BAC rises the rewarding effects of the drug become more pronounced, resulting in a corresponding decrease in attention towards alcohol cues.

The decrease in attentional bias following alcohol observed in heavy drinkers suggests that attentional bias might not play an influential role in promoting heavy alcohol consumption once a drinking episode has begun. This is further supported by the failure to observe significant differences in magnitude of attentional bias in heavy and light drinkers in response to either active dose of alcohol, as well as the lack of association between attentional bias under alcohol and any measure of self-reported or ad lib alcohol consumption in the current study. As such, it is likely that other factors (e.g., greater sensitivity to the rewarding or disinhibiting effects of the drug) are more influential in promoting excessive, binge-like consumption once a drinking episode has

been initiated. Indeed, in the current study I observed that desire for more alcohol following both active doses predicted both ad lib and self-reported alcohol consumption measures. Specifically, individuals reporting greater desire for alcohol following the active doses self-reported greater consumption levels over the past three months, as well as consumed more when given ad lib access. This provides additional support for the hypothesis that acute interoceptive rewarding effects of the drug take on a heightened importance and play a significant role in influencing further alcohol consumption.

The discrepancies between the current findings and those reported from previous investigations of alcohol effects on attentional bias highlight the importance of examining attentional bias in well-defined drinker groups based on a priori criteria. Previous studies examined attentional bias in single samples comprised of individuals with heterogeneous drinking habits, and this may have contributed to the failure of these studies to demonstrate any attentional bias in the sober state (i.e., in the placebo condition) (Duka & Townshend, 2004; Schoenmakers et al., 2008). However, by examining attentional bias separately in distinct drinker groups, I was able to observe robust attentional bias in the heavy drinkers and marked group differences in response to alcohol. My group selection scheme was based on a strictly characterized drinking parameter (i.e., frequency of binge drinking), which was first obtained in a phone interview and then confirmed via a well-validated retrospective measure of alcohol consumption and by using BAC estimation formulae that take into consideration a number of variables, including gender, weight, and quantity and duration of individual drinking episodes. Moreover, study results provided strong validation for my selection criteria, as evidenced by the pronounced group differences in measures of both ad lib alcohol consumption in the laboratory and

self-reported quantity and frequency of consumption. As such, selection of heavy, binge drinkers allowed for observation of changes in attentional bias in response to alcohol that were not observed in moderate drinkers, who are more commonly studied.

There are some potential limitations to this study. First, the lack of a sober control condition makes it difficult to interpret the degree to which attentional bias observed in the placebo condition is due to the expectancy of alcohol. However, given that previous research has consistently shown marked attentional bias in heavy drinkers with no expectancy of alcohol (e.g., Murphy & Garavan, 2011; Townshend & Duka, 2001) it is unlikely that the current observations were due solely to expectancy effects. Additionally, the current study focused on attentional bias soon after alcohol consumption, as BAC was rising. In order to better understand fluctuations in attentional bias throughout a drinking episode, as well as the role of attentional bias in initiating or maintaining various phases of the drinking episode, it will be important to investigate attentional bias across the blood alcohol curve. Future studies investigating alcohol effects on both the ascending and descending limbs of the blood alcohol curve, with a particular emphasis on declining BACs, would provide valuable information concerning other potential means through which this mechanism might serve to promote excessive alcohol consumption. Finally, methodological limitations of the visual probe task could potentially reduce the ability to measure attentional bias under higher doses. Overall fixation time recorded by the eye-tracking equipment for this task was decreased dose-dependently by alcohol, and this could have significant implications for measurement of attentional bias. The reduction in fixation time could be due to impairment of ocular functioning and attentional mechanisms in response to the drug (Miller & Fillmore, 2011; Rohrbaugh et al., 1988;

Stapleton, Guthrie, & Linnoila, 1986), as well as to technological limitations of the eye-tracking device. Additionally, the specific images presented in the visual probe task were varied in terms of type of alcoholic beverage (i.e., wine, liquor, and beer images were each presented). As an individual's alcohol preference would likely influence the specific cues to which a bias is shown, this could also decrease the sensitivity of this task. Finally, the task had to be performed in the dark in order to use the eye-tracking equipment. This might have contributed to increased alcohol-induced sedation, with potential carry-over effects on task performance. It will be important for futures studies to replicate these findings using alternate measures of attentional bias to confirm that the current results are not an artifact of measurement bias.

In sum, this study provides new information regarding the acute effects of alcohol on attentional bias towards alcohol-related cues in both heavy and moderate drinkers. The findings point to a role of attentional bias as a motivational factor for alcohol consumption that might be specific to the initiation of a drinking episode, and less relevant in regard to continuation or prolonging of the episode. These findings have potential implications for understanding means through which attentional bias serves to promote alcohol consumption, and how that influence might fluctuate within a drinking episode.

Table 2.1
Drinking Habits and Demographic Measures by Drinker Group

	Group				Contrasts
	Heavy (*n* = 20)		Moderate (*n* = 20)		
	M	*SD*	*M*	*SD*	
TLFB (past 12 weeks)					
Binge days	26.0	7.2	3.3	3.0	Sig***
"Drunk" days	17.8	9.3	3.0	2.9	Sig***
Drinking days	38.5	14.7	22.5	11.6	Sig***
Total drinks consumed	288.9	133.9	66.4	34.1	Sig***
Demographics					
Gender (male:female)	12:8		10:10		*ns*
Weight (kg)	72.4	12.3	72.7	12.8	*ns*

Note. Group contrasts were tested by between-groups *t* tests. Sig*** indicates a significance value of $p < .001$.

Table 2.2

Mean (SD) Fixation Times on Alcohol-related and Neutral Images by Drinker Group

	Group			
	Heavy		Moderate	
Dose	Alcohol	Neutral	Alcohol	Neutral
0.0 g/kg (placebo)	378.2 (34.7)	315.4 (44.3)	362.7 (63.1)	343.3 (49.6)
0.45 g/kg	340.5 (44.5)	302.3 (66.2)	344.6 (74.0)	323.8 (54.9)
0.65 g/kg	325.1 (58.8)	301.1 (56.5)	341.9 (52.8)	310.2 (53.1)

Table 2.3

Mean (SD) Ad Lib Consumption Measures by Drinker Group

	Group				Contrasts
	Heavy		Moderate		
	M	*SD*	*M*	*SD*	
Beer consumed (ml)	1495.6	567.8	865.7	515.7	Sig**
Weight-adjusted dose (mg/kg)	20.2	6.8	12.1	7.8	Sig**
Ad lib BAC (mg/100ml)	64.5	29.4	34.9	29.4	Sig**

Note. Group contrasts were tested by between-groups *t* tests. Sig** indicates a significance value of $p < .01$.

Table 2.4

Correlation Matrix of Attentional Bias Scores with Ad Lib and Self-reported Alcohol Consumption

	Attentional Bias Score		
	0.0 g/kg (placebo)	0.45 g/kg	0.65 g/kg
Ad Lib Measures			
Beer consumed	**.33***	.12	.12
Dose consumed	**.33***	.16	.21
Ad lib BAC	.30	.15	.19
TLFB			
Binge days	**.45****	.19	.02
"Drunk" days	**.36***	.11	.03
Drinking days	**.36***	.09	.18
Total drinks consumed	**.51****	.17	.02

Note. ***** indicates a significance value of $p < .05$ and ****** indicates a significance value of $p < .01$.

Table 2.5

Correlation Matrix of Desire for Alcohol Ratings with Ad Lib and Self-reported Alcohol Consumption

	Desire for Alcohol		
	0.0 g/kg (placebo)	0.45 g/kg	0.65 g/kg
Ad Lib Measures			
Beer consumed	.01	**.32***	**.36***
Dose consumed	.07	**.34***	**.38***
Ad lib BAC	.06	**.39***	**.44****
TLFB			
Binge days	.01	.29	**.37***
"Drunk" days	.14	**.48****	**.52****
Drinking days	.06	**.34***	.18
Total drinks consumed	-.01	**.34***	**.35***

Note. ***** indicates a significance value of $p < .05$ and ****** indicates a significance value of $p < .01$.

Figure 2.1

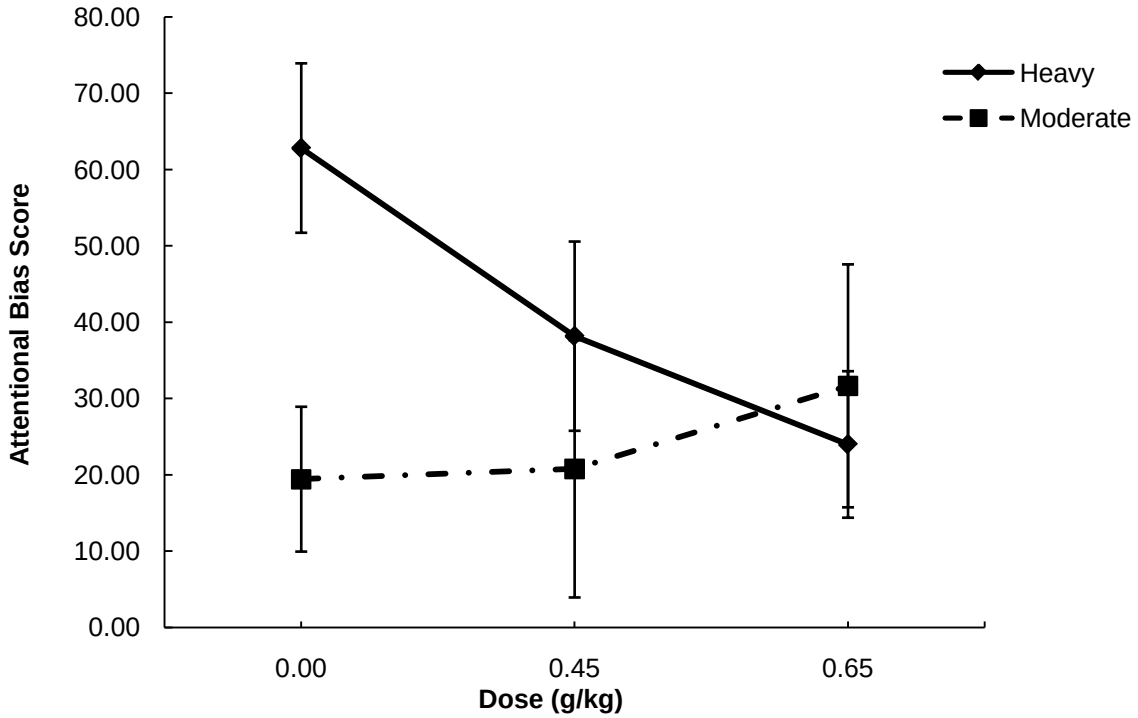

Figure 2.1. Mean attentional bias scores for the heavy and moderate drinker groups under three alcohol doses: 0.0 g/kg (placebo), 0.45 g/kg, and 0.65 g/kg. Capped vertical lines show standard errors of the mean.

Figure 2.2

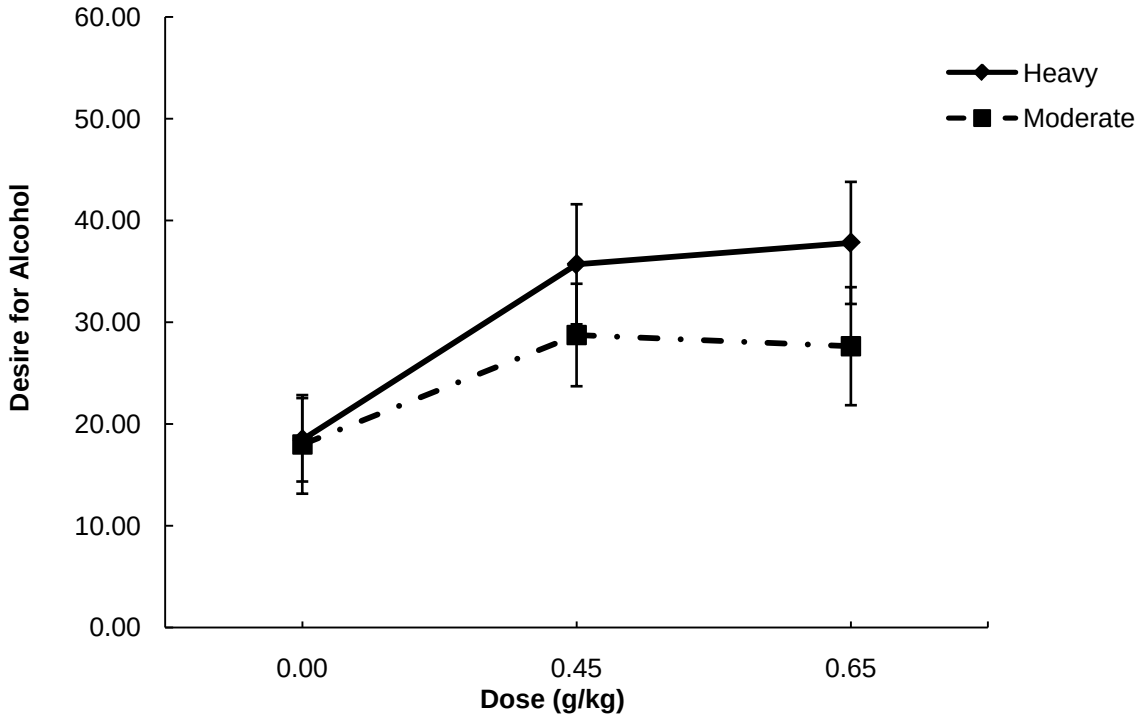

Figure 2.2. Mean self-reported ratings of desire for alcohol for the heavy and moderate drinker groups under three alcohol doses: 0.0 g/kg (placebo), 0.45 g/kg, and 0.65 g/kg. Capped vertical lines show standard errors of the mean.

Chapter 3

THE EFFECTS OF ALCOHOL STIMULI ON INHIBITORY CONTROL IN DRINKERS

(STUDY 2; Weafer & Fillmore)

Introduction

Research on alcohol abuse has begun to focus considerable attention on the role of cognitive mechanisms in excessive and harmful alcohol consumption. One specific cognitive factor that has been shown to be strongly associated with alcohol abuse is that of behavioral control (Fillmore, 2003; Finn, Kessler, & Hussong, 1994; Lyvers, 2000). Generally speaking, impaired control mechanisms increase the difficulty alcohol abusers often experience in suppressing urges to consume the drug. As such, disinhibited consumption persists, despite the occurrence of numerous negative alcohol-related consequences. A second cognitive factor that has been found to be relevant to alcohol abuse is that of cognitive biases related to alcohol and alcohol-related stimuli (Field & Cox, 2008; Ryan, 2002; Stacy & Wiers, 2010). Alcohol abusers have been shown to focus increased attention towards alcohol-related cues (i.e., "attentional bias") compared to light or non-drinkers, and to display a biased interpretation of such cues as being more positive or arousing. Moreover, attention directed towards alcohol-related stimuli is thought to increase urges to consume alcohol, thereby promoting increased use. Both cognitive mechanisms of behavioral control and attentional bias are often examined both as chronic, stable characteristics of an individual, and as malleable factors that are sensitive to environmentally-influenced fluctuations (Field et al., 2010; Fillmore, 2003; Lyvers, 2000). Moreover, some researchers have begun to speculate as to how these two

mechanisms might serve to reciprocally influence each other in such a way that would promote excessive consumption (e.g., Goldstein & Volkow, 2002). The current study sought to experimentally investigate this potential interaction through the integration of behavioral control and attentional bias models.

Cognitive models of behavioral control date back several decades. Theorists typically describe behavioral control as governed by two independent processes: an activational process and an inhibitory process (Fowles, 1987; Gray, 1976; Logan & Cowan, 1984). The activational process is responsible for executing a behavioral response, whereas the inhibitory process is responsible for inhibiting inappropriate or unwanted behavior. These two processes act in opposition, and behavior is assumed to occur based on the relative strength of each. Laboratory tasks designed to model these two processes (e.g., go/no-go tasks, stop signal tasks) have been utilized to examine behavioral control in substance abusers (e.g., Bjork, Hommer, Grant, & Danube, 2004; Rubio et al., 2008). These tasks typically require the execution of quick responses to go targets, and the inhibition of responses when stop signals or no-go targets are presented. Reaction time to go targets provides a measure of response activation, and failure to inhibit responses to no-go targets provides a measure of inhibition. Speed of response is encouraged, facilitating greater response activation and increasing difficulty of inhibition.

Studies of alcohol abuse utilizing these tasks have provided evidence for associations between deficits in behavioral control and greater alcohol consumption and alcohol-related problems. For example, our lab has shown that a greater number of inhibitory failures on a cued go/no-go task is associated with greater alcohol consumption in both adults with ADHD and controls (Weafer, Milich, & Fillmore, 2011). Similarly,

Rubio et al. (2008) showed that heavy drinkers displayed slower response inhibition on a stop-signal task compared with moderate drinking controls, and studies using continuous performance tasks show that detoxified alcoholics commit more commission errors (i.e., inhibitory failures) compared to controls (e.g., Bjork et al., 2004). Further, the acute impairing effects of alcohol on behavioral control are also well-established, and the disinhibiting effects of the drug are thought to play a role in its abuse potential (Fillmore, 2003, 2007). For instance, binge drinkers show greater alcohol-induced impairment of inhibitory control compared to non-binge drinkers (Marczinski et al., 2007), and individual differences in sensitivity to alcohol-induced disinhibition have been shown to predict levels of ad lib alcohol consumption (Weafer & Fillmore, 2008). In sum, a wealth of research has provided a strong link between impaired mechanisms of behavioral control and alcohol abuse.

A separate line of research has focused on the role of selective attention for alcohol-related cues in alcohol abuse. Attentional bias for alcohol stimuli is theorized to originate as a result of a history of heavy alcohol use through classical conditioning (Field & Cox, 2008; Franken, 2003). According to the incentive sensitization theory (Robinson & Berridge, 1993, 2001), as substance-related cues are repeatedly paired with drug administration over a prolonged period of drug use, the cues come to be associated with both drug consumption and motivation for consumption. As a result, drug-related stimuli become increasingly salient for users, resulting in greater attentional orienting towards the cues when they are encountered in the environment. Further, drug-related cues take on high incentive-motivational properties, eliciting increased motivation for, and behavioral activation of, drug-seeking and drug-taking.

Several laboratory measures have been developed to assess attentional bias. Recent studies have focused on the visual probe task, which presents alcohol-related and neutral stimuli side by side on a computer screen. Eye-tracking equipment records the amount of time participants spend fixating on each image, and longer fixation on alcohol compared to neutral images is thought to reflect an attentional bias to alcohol-related stimuli (Miller & Fillmore, 2010, 2011; Schoenmakers et al., 2008). Studies utilizing this and other similar tasks have provided consistent evidence for greater attentional bias in heavy drinkers compared to light drinkers (Field, Christiansen, et al., 2007; Murphy & Garavan, 2011; Sharma et al., 2001; Tibboel et al., 2010; Townshend & Duka, 2001), and in treatment-seeking alcoholics compared to social drinking controls (e.g., Jones et al., 2006). Additionally, individual difference analyses have shown that magnitude of attentional bias predicts level of consumption and alcohol problem severity in both social drinkers (Ceballos et al., 2009; Fadardi & Cox, 2008; Miller & Fillmore, 2010; Murphy & Garavan, 2011) and alcoholics (Jones et al., 2006).

To date, research on deficient behavioral control and research on attentional bias in alcohol abusers have each proceeded as fairly independent lines of inquiry. However, the potential confluence of these two cognitive mechanisms in the etiology and maintenance of drug abuse has been well recognized for some time (Dawe et al., 2004; Goldstein & Volkow, 2002; Jentsch & Taylor, 1999). These mechanisms are hypothesized to work simultaneously and potentially interactively to increase the likelihood of unregulated alcohol-seeking and prolonged alcohol consumption. For instance, attention directed towards alcohol cues could serve to acutely disrupt mechanisms of behavioral control. That is, the stronger the motivational response elicited

by the cue, the more difficult it should be to inhibit a behavioral response to seek out the cue (and the drug). As such, in heavy drinkers, attention towards alcohol-related stimuli might result in increased behavioral activation and impaired mechanisms of inhibitory control. However, despite speculation regarding the disruptive effect of attentional bias on behavioral control mechanisms, this hypothesis has received little experimental investigation.

For the current study, I sought to develop a novel behavioral task to investigate the hypothesized disruptive effect of alcohol-related stimuli on inhibitory and activational mechanisms of behavior. I modified a cued go/no-go task that has been used extensively in alcohol abuse research (Fillmore, 2003, 2007). The task presents cues that signal that a response will be required. The cues serve to increase response activation and to make inhibition difficult on the occasional instances when the response must be suddenly inhibited. In traditional cued go/no-go tasks, the cues are typically arbitrary symbols (e.g., geometrical shapes). However, in my adapted task, the Attentional Bias-Behavioral Activation (ABBA) task, alcohol-related images serve as cues. As such, the ABBA task allows for an experimental examination of the degree to which alcohol cues themselves serve to disrupt behavioral control. It was hypothesized that, for individuals with a history of moderate to heavy alcohol consumption, alcohol cues would increase response activation (speed reaction time) and impair inhibitory control (increase the frequency of inhibitory failures).

To date, only a small number of studies have examined behavioral control mechanisms in response to alcohol cues. Noel et al. (2007) administered a go/no-go task that presented alcohol-related and neutral words as targets and distracters. Overall,

participants responded faster to alcohol targets compared to neutral targets, and more commission errors were observed to alcohol distracters. Rose and Duka (2008) administered a similar go/no-go task that presented alcohol-related and neutral pictures as targets. Here, the authors reported a slowing effect of alcohol stimuli on response activation, and no effect of alcohol stimuli on inhibitory errors. In a third study, Nederkoorn et al. (2009) examined performance on a stop signal task in which stimuli consisted of alcohol-related and neutral pictures; however, results showed no effect of alcohol stimuli on response inhibition. Although it is unclear why the two studies that utilized pictures as stimuli (i.e., Nederkoorn et al., 2009; Rose & Duka, 2008) failed to observe a disruptive effect of alcohol cues on behavioral control, it is important to note that neither study included an independent measure of attentional bias. Alcohol stimuli would only be expected to affect behavioral control in individuals who have developed some degree of attentional bias to alcohol-related cues. With no assessment of such a bias, it is unknown if alcohol images would have captured attention in order to influence the participants' behavior in these studies.

The current study included an independent measure to verify attentional bias in participants, and to test the hypothesis that individuals who display greater attentional bias to alcohol stimuli would also display a greater disruption of behavioral control in response to alcohol cues. The Scene Inspection Paradigm (SIP), a novel measure of attentional bias developed in our laboratory, presents a series of images consisting of commonly encountered real-life scenarios (e.g., party, dinner setting), which contain an element of alcohol-related content. Participants inspect the images and eye-tracking software is used to monitor their viewing patterns. The total amount of time a participant

spends focusing on the alcohol content is measured, and longer viewing time on alcohol content represents a greater attentional bias. This measure of attentional bias differs from traditional visual probe measures, in that it presents alcohol cues within a more "real-life" and ecologically valid scenario. Specifically, the SIP presents alcohol cues as they are encountered in the environment (e.g., an individual carrying a pitcher of beer; a glass of beer on a table in a restaurant). This allows for a measurement of the degree to which alcohol stimuli capture attention in the context of other interesting, competing stimuli (e.g., human faces), and as such might provide a better understanding of how attention towards these cues operates to promote alcohol consumption outside of the laboratory.

In sum, the current study aimed to integrate two lines of research involving mechanisms theorized to be associated with alcohol abuse (i.e., impaired behavioral control and attentional bias) through the utilization of two novel laboratory tasks. A sample of moderate to heavy drinkers was recruited to perform the ABBA task and the SIP. It was hypothesized that participants would display greater disruption of behavioral control in the presence of alcohol cues, as evidenced by greater response activation and impaired response inhibition. Further, I hypothesized that those whose behavioral control was most disrupted by alcohol images on the ABBA task would also display the greatest attentional bias on the SIP.

Methods

Participants

Fifty adult beer drinkers (20 women and 30 men) between the ages of 21 and 29 (mean age = 23.9, *SD* = 2.6) were recruited to participate in this study. Screening measures were conducted to determine medical history and current and past drug and

alcohol use. Any volunteers who self-reported head trauma, psychiatric disorder, or substance abuse disorder were excluded from participation. Volunteers were recruited via notices placed on community bulletin boards and by university newspaper advertisements. The University of Kentucky Institutional Review Board approved the study, and participants received $30 for their participation.

Materials and Measures

Attentional Bias-Behavioral Activation (ABBA) Task. The ABBA task, a modified cued go/no-go reaction time task, was operated using E-prime experiment generation software (Psychology Software Tools, Pittsburgh, PA) and was performed on a PC. A trial involved the following sequence of events: (a) presentation of a fixation point (+) for 800 ms; (b) a blank white screen for 500 ms; (c) a cue image (alcohol or neutral), displayed for one of five stimulus onset asynchronies (SOAs = 100, 200, 300, 400, and 500 ms); (d) a go or no-go target, which remained visible until a response occurred or 1,000 ms had elapsed; and (e) an intertrial interval of 700 ms.

The cues consisted of alcohol-related images (e.g., beer can, six-pack of beer bottles) or neutral images (e.g., stapler, paper towel roll). These were 15 cm X 11.5 cm images presented in the center of the computer monitor against a white background. The alcohol beverage type was always beer. After an SOA the cue image turned either solid green (go target) or solid blue (no-go target). Participants were instructed to press the forward slash (/) key on the keyboard as soon as a green (go) target appeared and to suppress the response when a blue (no-go) target was presented. Key presses were made with the right index finger. A schematic of a trial in which an alcohol cue turns into a go target is presented in Figure 3.1.

The task consisted of two conditions: *alcohol go* condition and *neutral go* condition. In the *alcohol go* condition, alcohol images turned into the go target on 80% of trials and turned into the no-go target on only 20% of trials. Therefore, alcohol images operated as go cues, based on the high probability that they would signal go targets most of the time. As such, these images should speed reaction time (RT) to the go targets, but also increase failures to inhibit the response when the no-go target is occasionally presented. By contrast, in the *neutral go* condition the opposite cue image-target pairings were presented. Therefore, in this condition neutral images served as go cues, producing faster RT to go targets, but more inhibitory failures to the occasional presentation of no-go targets. By comparing the *alcohol go* condition and *neutral go* condition, the task measures the degree to which alcohol-related go cues elicit greater response activation, but poor inhibitory control, compared to neutral go cues.

A test consisted of 250 trials, split into 5 blocks of 50 trials each. For each trial, the computer recorded whether a response occurred and, if so, the RT in milliseconds was measured from the onset of the target until the key was pressed. To encourage quick and accurate responding, the computer presented feedback to the participant during the intertrial interval by displaying the words *correct* or *incorrect* along with the RT in milliseconds. Omission errors (when participants failed to respond to go targets) were also recorded. These were infrequent and occurred on less than 0.005% of go target trials (i.e., less than one trial per test). RTs from omission errors were excluded from analyses. Each block required approximately 2.5 min to complete and blocks were separated by 30 sec breaks, for a total test time of approximately 15 min.

Scene Inspection Paradigm (SIP). Attentional bias was measured by the SIP, operated on a Tobii T120 Eye Tracker (Tobii Technology, Sweden). Cameras are embedded into the Tobii monitor, providing an unobtrusive measure of eye movement that allows participants to sit comfortably, approximately 60 cm in front of the computer, with free range of head and neck motion. Participants were presented with 20 images (18.4 cm X 14.5) on the monitor in random order for 15 sec each. They were instructed to look at the images closely the entire time they were on the screen, ostensibly to prepare for a picture recognition test later in the session. Ten of the images portrayed common real-life scenes that included an element of alcohol-related content (e.g., a place setting at a restaurant containing beer bottles, people drinking beer in a bar). An example of one of these images is presented in Figure 3.2 (left panel). The alcohol content of the images was restricted to 15-30% of the total image size, and the alcohol beverage type was always beer. The remaining ten filler images also presented common real-life scenes that were matched for complexity, but contained no alcohol-related content.

The dependent measure of interest was the total amount of time participants spent focused on the alcohol-related content during presentation of the 10 critical images. Alcohol Areas of Interest (AOIs) were defined within the Tobii Visualization window by marking the area surrounding the specific alcohol-related content (e.g., bottle of beer) in each scene, as illustrated in Figure 3.2 (right panel). The eye-tracking equipment recorded the amount of time in sec each participant spent looking within each AOI. Tobii software provided a measure of total visit duration, which gave the total time each participant spent viewing alcohol-related content, summed across all of the ten critical images. Together the critical images were presented for a total of 150 sec (15 sec for each

of the 10 images), allowing for the total visit duration in alcohol AOIs to range from 0 to 150 sec. Longer total visit duration indicated greater attentional bias towards alcohol-related content of the images.

Barratt Impulsiveness Scale (*BIS; Patton, Stanford, & Barratt, 1995).* Participants completed the BIS to provide a self-report measure of trait impulsivity. Participants indicated how typical each of 30 statements (e.g., "I am self controlled") is for them on a 4-point Likert scale. Higher scores indicated greater total levels of impulsiveness.

Time Line Follow-Back (TLFB; Sobell & Sobell, 1992). Participants completed a retrospective time line calendar of their alcohol consumption for the past three months to assess daily patterns of drinking, including number of binge episodes. The measure uses "anchor points" to structure and facilitate participants' recall of past drinking episodes. For each day, participants estimated the number of standard drinks they consumed and the number of hours they spent drinking. This information, along with gender and body weight, was used to estimate the resultant BAC obtained for each drinking day. This was done using well-established, valid anthropometric-based BAC estimation formulae that assume an average clearance rate of 15 mg/100 ml per hour of the drinking episode (McKim, 2007; Watson et al., 1981). These formulae have been used in previous studies and have been shown to yield high correlations with actual resultant BACs obtained under laboratory conditions (Fillmore, 2001). Any day in which the estimated resultant BAC was 80 mg/100 ml or higher was classified as a binge episode (NIAAA, 2004). The TLFB provided three measures of drinking habits over the past three months: (a) binge days (total number of binge episodes); (b) drinking days (total number of days alcohol was consumed); (c) total drinks (total number of drinks consumed over the three months).

Procedure

Interested volunteers responded to study advertisements by calling the laboratory to participate in an intake-screening interview conducted by a research assistant. At that time, they were informed that the purpose of the study was to examine performance on cognitive tasks. Volunteers were asked to report their preferred alcoholic beverage (beer, wine, or liquor). Because all alcohol-related stimuli consisted of beer images, only those reporting beer as their preferred beverage were eligible for study participation. Eligible participants made appointments to attend the 1.5 hour testing session in the Behavioral Pharmacology Laboratory of the Department of Psychology. All participants were tested individually. At the beginning of the session participants provided informed consent for participation. Participants' heights and weights were measured, and urine samples were tested for drug metabolites, including amphetamine, barbiturates, benzodiazepines, cocaine, opiates, and tetrahydrocannabinol (ON trak TesTstiks, Roce Diagnostics Corporation, Indianapolis, IN, USA). Breath samples were measured by an Intoxilyzer, Model 400 (CMI, Inc., Owensboro, KY, USA) to verify a zero blood alcohol concentration (BAC).

Men and women were randomly divided into two groups upon initiation into the study. Half of participants were assigned to the *alcohol go* task condition, and half were assigned to the *neutral go* condition, such that gender make-up was equivalent across groups. All participants first performed the SIP, which took approximately five minutes to complete, followed by the ABBA task. Task order was kept constant to prevent any carry over influence of ABBA task condition assignment on SIP performance. Participants completed questionnaire measures, including demographics, impulsivity, and

alcohol consumption measures. Lastly, participants were debriefed and compensated for their participation.

Criterion Measures and Data Analyses

ABBA (Behavioral Control). Performance in the *alcohol go* condition and the *neutral go* condition was compared to test the degree to which alcohol images increased response activation and decreased response inhibition relative to neutral images. Both RT and the proportion of inhibitory failures (p-inhibitory failures) were analyzed by between-groups *t*-tests.

SIP (Attentional Bias). The primary dependent variable for the SIP was total visit duration on alcohol AOIs during presentation of the 10 critical images. Correlational analyses were conducted to analyze the degree to which time spent focusing on alcohol stimuli in the SIP predicted RT and p-inhibitory failures on the ABBA, separately for the *alcohol go* and *neutral go* conditions.

Results

Demographics, Trait Impulsivity, and Drinking Habit Measures

Table 3.1 summarizes demographic data, trait impulsivity, and drinking habit measures for participants in the *alcohol go* and *neutral go* conditions. The groups did not differ significantly in age, trait impulsivity, or in any measure of alcohol consumption over the past 90 days as reported on the TLFB (*p*s > .25). The table shows that participants were frequent drinkers, reporting alcohol consumption on a mean of approximately 1/3 of the past 90 days. Moreover, on average, over 1/3 of those drinking days were binge episodes. These self-reported drinking patterns provide confirmation of participants' frequent moderate to heavy alcohol consumption.

ABBA Task Performance

Reliability. Intraclass correlation coefficients were calculated to estimate the reliability of individual participants' performance for both task conditions of the ABBA task. For each participant, mean response activation and inhibition scores were calculated for each of the five test blocks, and reliability of their performance across blocks was estimated by calculating the coefficients of consistency for each measure using Hoyt's formula (McGraw & Wong, 1996). For the *alcohol go* condition, RT and p-inhibition failures showed consistency coefficients of 0.94 and 0.92, respectfully. For the *neutral go* condition, RT and p-inhibition failures showed consistency coefficients of 0.95 and 0.77, respectively. Thus, individual differences among participants' performance showed consistency over the five test blocks in both task conditions.

Response Activation and Inhibition Following Go Cues. Mean RT following go cues for the *alcohol go* and *neutral go* conditions are presented in Figure 3.3 (left panel). The figure shows that mean RT was slightly faster to go targets that followed alcohol images compared to those that followed neutral images; however, a between-groups *t* test showed that this was not a significant difference ($p = .34$). Mean p-inhibitory failures to no-go targets that followed go cues are presented in Figure 3.3 (right panel). The figure shows greater frequency of inhibitory failures following alcohol images compared to neutral images. A between-groups *t* test confirmed that mean p-inhibitory failures were greater in the *alcohol go* condition compared to the *neutral go* condition, $t(48) = 2.2$, $p = .03$, $d = .63$.

Response Activation and Inhibition Following No-go Cues. RT was expected to be slowed and p-inhibitory failures infrequent following no-go cues, and as such cue

image type was expected to have little influence on response activation and inhibition. Mean RT and p-inhibitory failures to no-go cues are presented in Table 3.2. The table shows that, as expected, mean RT and p-inhibitory failures were comparable in both conditions, and between-groups *t* tests showed no difference in mean RT (p = .75) or p-inhibitory failures (p = .07) between the conditions.

Scene Inspection Paradigm (SIP).

Reliability. Internal consistency of time spent focusing on alcohol images on the SIP task was calculated by a split-half reliability coefficient. The 10 alcohol images were split into two sets of five images each (i.e., even-numbered images and odd-numbered images), and yielded a split-half reliability coefficient of 0.83. Thus the degree of attention allocated to alcohol stimuli was reliably observed across images.

Associations with Drinking Habits. Attentional bias as measured by the SIP was examined in the sample as a whole. Mean attentional bias (i.e., mean time spent fixated on alcohol AOIs) was 59.2 sec (SD = 12.9). There was considerable variability within the sample, with alcohol fixation time ranging from 25.1 to 90.0 sec. In order to validate the SIP as a measure of attentional bias, it was necessary to confirm that participants' alcohol fixation times were associated with their alcohol consumption. To test this, I conducted bivariate correlational analyses between alcohol consumption measures as reported on the TLFB and participants' alcohol fixation time on the SIP. Alcohol fixation time on the SIP showed a significant positive association with participants' number of binge days (r = .29, p = .04) and their total drinks consumed (r = .31, p = .03) over the past 90 days. Thus, individuals who reported consuming the greatest quantities of alcohol also spent the most time focusing on alcohol-related images in this paradigm. Attentional bias was

not related to number of drinking days (i.e., frequency of drinking) over the past 90 days (p = .73).

Associations with ABBA Performance. I tested the hypothesis that greater attentional bias on the SIP should predict greater response activation and poor inhibitory control following alcohol images on the ABBA task. Mean fixation time on the SIP was comparable for those in the *alcohol go* (mean = 61.1 sec, *SD* = 14.3) and *neutral go* (mean = 57.2, *SD* = 11.3) conditions, and this was confirmed by a between-groups *t* test (p = .28). Longer alcohol fixation times were associated with faster RT on the ABBA task for those in the *alcohol go* condition (r = -.43, p = .03), but no association between alcohol fixation times and p-inhibitory failures was observed (p = .50). Thus, individuals who displayed greater attentional bias also responded faster following alcohol images, but did not display more inhibitory failures. Alcohol fixation times showed no relation to either measure on the ABBA task for those in the *neutral go* condition (ps > .17).

Discussion

This study integrated two lines of research regarding the roles of behavioral control and attentional bias in alcohol abuse. Specifically, the study examined both the degree to which alcohol images served to disrupt mechanisms of behavioral control, and the extent to which individual differences in attentional bias predicted disruption of control in response to alcohol images. Participants performed a novel laboratory task that measured response activation and inhibition following alcohol-related and neutral images. Results showed that inhibitory failures were more frequent following alcohol images compared to neutral images. Further, the study examined attention to alcohol content on a novel measure of attentional bias. Validation for this measure was provided

by significant associations between heightened attentional bias on the SIP and greater self-reported measures of quantity of alcohol consumption. Moreover, individual differences in attentional bias predicted response activation, but not response inhibition, following alcohol images on the ABBA task. That is, those who fixated on alcohol content for the longest time on the SIP also displayed the fastest responses following alcohol images on the ABBA task. No significant associations were found regarding attentional bias and response activation or inhibition following neutral images.

These findings provide evidence in support of the hypothesis that, in addition to capturing attention, alcohol cues can disrupt mechanisms of behavioral control, particularly in terms of response inhibition. Moreover, results showed a significant association between heightened attentional bias and greater response activation following alcohol images. Theoretical accounts of attentional bias propose that attention towards alcohol stimuli elicits motivation to seek out and consume alcohol in heavy drinkers (Franken, 2003; Ryan, 2002). This motivation is thought to increase activation of alcohol-seeking behavior and weaken inhibitory mechanisms necessary to control such behavior. The current findings provide some of the first experimental evidence of impaired behavioral control mechanisms in response to alcohol cues. Further, this disruption was most pronounced in individuals displaying a heightened attentional bias toward alcohol stimuli. This provides support for a general conditioning effect in heavy drinkers that both increases attentional bias towards alcohol stimuli, and also results in reduced behavioral control in the presence of those stimuli.

By integrating two mechanisms that have been primarily tested independently in the past, the current study adds important information regarding the specific means

through which both behavioral control and attentional bias might serve to promote alcohol consumption. It is well-established that impaired control mechanisms are associated with alcohol abuse (Fillmore, 2003, 2007; Jentsch & Taylor, 1999; Lyvers, 2000). However, behavioral control has typically been assessed in response to arbitrary stimuli. In terms of "real world" situations, individuals attempting to control alcohol use must do so in the face of meaningful alcohol cues with potentially strong motivational properties. It is important to consider how behavioral control is compromised when alcohol stimuli are encountered, as this provides a more relevant and ecologically valid understanding of disruption of control mechanisms in high-risk alcohol consumption scenarios. As for attentional bias, it is well-established that a more pronounced attentional bias is associated with greater alcohol consumption and alcohol-related problems (Field & Cox, 2008). However, causal mechanisms through which a bias towards alcohol cues might promote consumption are not well understood. The current findings provide evidence suggesting that attention to the cues serves to increase response activation and decrease response inhibition. In terms of real world implications, it could be that attention to alcohol cues encountered in the environment could increase behavioral activation towards seeking out alcohol, and impair inhibitory mechanisms necessary to suppress or curtail alcohol-seeking and consumption.

To my knowledge, this is the first study to show a disruptive effect of alcohol-related images on behavioral control. Several methodological distinctions exist between the current study and previous studies that similarly examined inhibition in response to alcohol cues (e.g., Nederkoorn et al., 2009; Rose & Duka, 2008) that could potentially explain the inconsistencies in findings. First, the current study included the SIP to

independently verify attentional bias in participants, and more importantly, to confirm that performance on the ABBA task following alcohol images was related to attentional bias. Further, in the current study all alcohol stimuli consisted of beer images and only participants who reported beer as their preferred alcoholic beverage were eligible to participate. This ensured that all participants had significant drinking experience with the stimuli presented, and allowed for a more sensitive test of conditioned responses to alcohol stimuli.

The between-subjects design might be a potential limitation of the current study, as it is possible that the groups differed in baseline levels of inhibitory control. However, it is important to note that all participants were recruited from the same population of young adults and randomly assigned to conditions. I obtained comprehensive reports of demographic data, drinking habits, and trait impulsivity, and I was able to show that the groups did not differ on any of these measures, nor did the groups differ in attentional bias as measured by the SIP. However, it will be important for future studies to include an independent measure of inhibitory control to rule out the possibility that differences in performance between groups might be due to pre-existing group differences in inhibitory control. Alternately, the ABBA task could potentially be modified for future studies such that all participants perform both task conditions, allowing for a within-subjects comparison of inhibitory control following both alcohol and neutral cues.

There are several important questions that can be addressed using the ABBA task and the SIP that were beyond the scope of the present study. For instance, these tasks could be utilized to examine the effects of acute alcohol administration on response activation and inhibition in the context of alcohol cues. The acute disinhibiting effects of

alcohol are well-established (Fillmore, 2003, 2007), and are thought to play a role in excessive, episodic drinking (i.e., binge drinking) (Fillmore, 2007; Marczinski et al., 2007; Weafer & Fillmore, 2008). It is likely that alcohol's disinhibiting effects might be even more pronounced when inhibition must take place following alcohol cues. Moreover, this is a more ecologically valid measure of the type of behavioral control necessary to terminate a drinking episode once it has been initiated. That is, the decision to stop alcohol consumption once it has begun is likely to be executed in the presence of alcohol cues. If, as these results suggest, behavioral control is disrupted in response to alcohol stimuli, and if the disruption is even more pronounced in response to alcohol, this could be an important factor in promoting excessive alcohol consumption, particularly for individuals attempting to limit or control their drinking. A second question that should be addressed in future research is how other drug-related stimuli (in addition to alcohol) might produce similar disruption of control mechanisms. Evidence of increased attentional bias toward drug-related stimuli has been reported across several different addictive drugs, including cocaine, heroin, and cigarettes (Chanon, Sours, & Boettiger, 2010; Dunning et al., 2011; Waters, Marhe, & Franken, 2012). It is possible that attention to these stimuli could also increase response activation and impair inhibitory control, thus contributing to the difficulty abusers of these substances experience in resisting drug use when such stimuli are encountered in the environment. Examination of the degree to which the current findings generalize to other drugs of abuse will provide important information regarding the role of drug-related stimuli in substance use and abuse.

Table 3.1
Mean Demographics, Trait Impulsivity, and Drinking Habits by Condition

	Condition				Contrasts
	Alcohol Go		*Neutral Go*		
	M	*SD*	*M*	*SD*	
Demographics					
Gender (F:M)	10:15		10:15		ns.
Age	23.7	2.2	24.1	2.9	ns.
Barratt Impulsiveness Scale	65.4	9.9	62.6	7.0	ns.
TLFB (past 90 days)					
Binge Days	11.4	10.1	11.2	11.1	ns.
Drinking Days	28.4	16.1	27.6	13.2	ns.
Total Drinks Consumed	164.9	148.8	127.2	86.1	ns.

Note. Contrasts were tested by one-way between-groups ANOVAs. Ns. indicates a significance value of $p > .05$.

Table 3.2

Mean Reaction Time and P-inhibitory Failures to No-go Cues by Image Type

	Reaction Time		P-Inhibitory Failures	
	M	SD	M	SD
Alcohol Image	332.8	28.2	.04	.04
Neutral Image	336.2	45.3	.08	.09

Figure 3.1

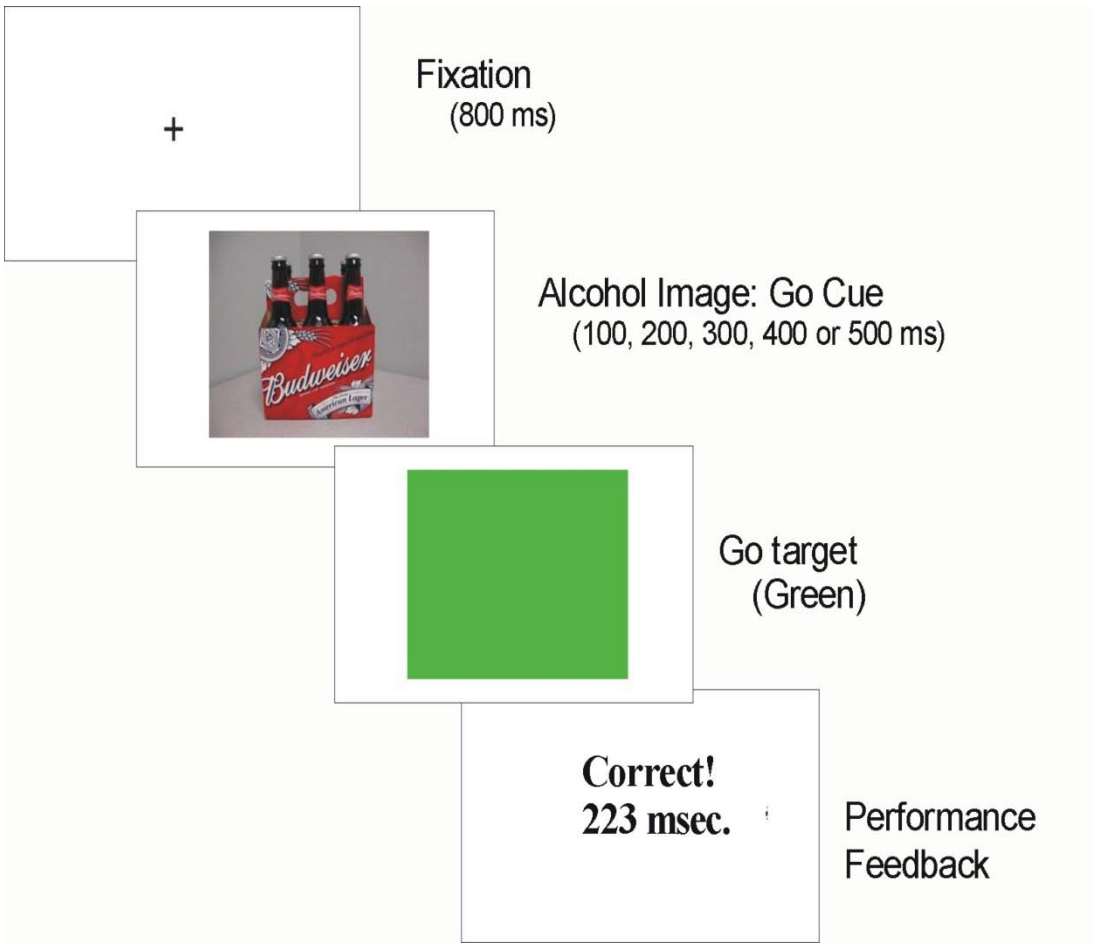

Figure 3.1. Schematic of a trial in the *alcohol go* condition on the ABBA task. Following the fixation point, an alcohol image is presented. Alcohol images precede go targets on the majority of trials in this condition, and as such alcohol images serve as go cues and increase behavioral activation. The go target is then presented, and the participant executes the response as quickly as possible. The computer provides feedback immediately following the response

Figure 3.2

Figure 3.2. Example of one of the 10 images presented on the SIP task containing alcohol-related content (left panel). The amount of time participants spent fixated on the alcohol AOI (right panel) was recorded for each image.

Figure 3.3

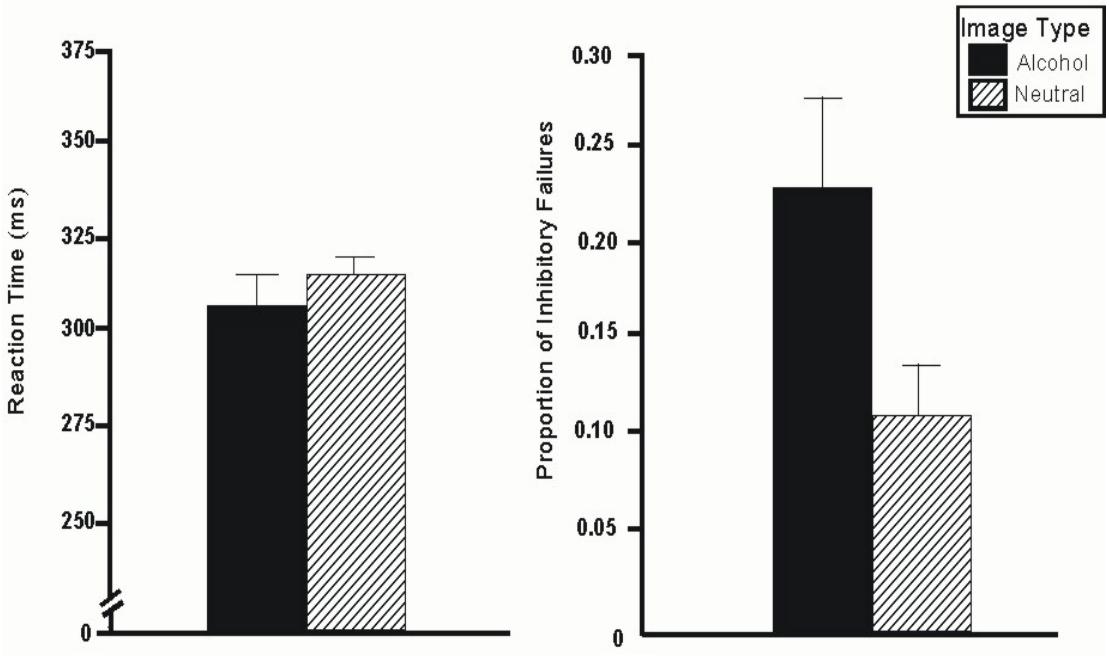

Figure 3.3 Mean RT (left panel) and p-inhibitory failures (right panel) to go cues following alcohol and neutral images on the ABBA task. Capped vertical lines represent standard errors of the mean

Chapter 4

GENERAL DISCUSSION

This dissertation examined specific mechanisms through which attentional bias might operate to promote alcohol consumption. Study 1 tested the hypotheses that alcohol would increase attentional bias in heavy drinkers, and that alcohol-induced increase in bias would predict greater levels of alcohol consumption. Results showed a pronounced attentional bias in heavy compared to light drinkers in response to placebo, as well as significant associations between attentional bias in the placebo condition and self-reported and ad lib alcohol consumption. However, contrary to hypotheses, heavy drinkers displayed a dose-dependent decrease in attentional bias following alcohol consumption, and attentional bias in intoxicated individuals was not associated with any measures of alcohol consumption. Study 2 tested the hypothesis that attention to alcohol-related stimuli could directly influence behavior through disruption of inhibitory control mechanisms. Results showed that alcohol stimuli did in fact impair response inhibition, and that individuals who displayed a greater magnitude of attentional bias experienced the most pronounced disruption of behavior in response to alcohol cues.

Taken together, these studies provide strong evidence for the association between attentional bias in sober individuals and heavy alcohol consumption. This was observed across multiple measures of both attentional bias (i.e., the traditional visual probe measure and the novel SIP measure) and alcohol consumption (i.e., self-reported and ad lib consumption). Further, attentional bias predicted drinking measures in sober individuals when measured both with and without a placebo alcohol expectancy. These findings add to the growing body of literature suggesting that attentional bias plays an

important role in the initiation of alcohol consumption (e.g., Field & Eastwood, 2005; Fadardi & Cox, 2009). However, the exact nature of that role is still poorly understood. The next section discusses possible interpretations of the association between attentional bias and consumption, and how such a bias might serve to contribute to excessive drinking.

Attentional Bias: Cause or Consequence of Motivation to Drink?

Although the associations observed in this dissertation between magnitude of attentional bias and alcohol consumption measures are correlational and therefore preclude any causal inferences, the findings can aid in speculation as to what such an increased salience of alcohol cues might mean for understanding motivation behind alcohol consumption. One possibility is that attentional bias towards alcohol cues is a direct result, or consequence, of increased motivation for alcohol consumption. That is, drinkers who are highly motivated to drink will display a heightened focus on alcohol cues, just as a hungry person who is highly motivated to eat will display a heightened focus on food-related cues. In this scenario, attentional bias would serve primarily as an indicator (or consequence) of motivation for consumption, without having any direct influence on motivation to drink. In regard to the current findings, this might imply that the alcohol-induced decrease in attentional bias observed in the heavy drinkers in Study 1 is the result of a satiation effect produced by the active doses of alcohol. That is, the drug effects may have been sufficiently intoxicating, to the point that participants were no longer motivated to consume further amounts. While this is certainly a possibility, this explanation is not entirely consistent with other findings from the study. For instance, the increase in self-reported desire (a presumed marker of motivation) for alcohol following

both active doses is in direct contrast to the dose-dependent decrease in attentional bias. It is true that these ratings of desire for alcohol are subject to the limitations inherent in self-report measures, including participant biases and experimenter demand characteristics, as well as lack of participant effort to accurately and honestly complete the measure (e.g., Rosenberg, 2009; Sayette et al., 2000), and as such might not provide an accurate representation of motivation for alcohol. However, correlational analyses revealed that self-reported desire following alcohol predicted both self-reported and ad lib consumption measures. Thus, the same individuals who self-reported the greatest desire for more alcohol following a dose also consumed the most when given ad lib access and self-reported greater consumption over the past three months.

Similarly, the pronounced attentional bias observed in sober heavy drinkers in these studies might not necessarily reflect a strong motivation for consumption at the time of testing. Again, the self-reported desire for alcohol under placebo was incongruent with the measure of attentional bias in Study 1; here, desire for alcohol was quite low and individual differences in this measure bore no relation to measures of alcohol consumption. Additionally, all participants were young adult, non-dependent drinkers for whom the majority of alcohol consumption took place socially on weekends. As such, it is unlikely that participants entered the laboratory environment with a strong urge to consume alcohol, especially for Study 2, which contained no expectancy of alcohol consumption. Taken together, the current results do not provide strong support for attentional bias as an indicator of motivation for alcohol.

A second possibility is that attentional bias serves as a causal factor in motivation to drink. That is, salient alcohol cues could capture the attention of drinkers irrespective

of their current motivational state, and subsequently directly influence motivation to consume alcohol. This is more in line with the incentive sensitization theory of Robinson and Berridge (1993) which proposes that attention to alcohol cues increases motivation to drink due to conditioned associations between the cues and rewarding effects of alcohol, as well as due to cue-induced dopamine release in the mesocortical pathway. Functional magnetic resonance imaging studies are beginning to provide evidence in support of alcohol cue-induced increase in activation of this reward pathway in both heavy drinkers and alcoholics, suggesting a potential casual link between attentional bias and motivation to drink (Ihssen, Cox, Wiggett, Fadardi, & Linden, 2011; Myrick et al., 2004; Vollstadt-Klein et al., in press). Further, previous studies have provided evidence that an increase or decrease in attentional bias can have a corresponding effect on alcohol consumption (Fadardi & Cox, 2009; Field & Eastwood, 2005; Schoenmakers et al., 2007). This dissertation did not manipulate attentional bias and therefore cannot directly address this question. However, the above-mentioned studies suggest that the ability of alcohol cues to "grab the attention" of heavy drinkers observed in the current studies could produce an increase in motivation for consumption. This is an intriguing question, and it will be important for future studies to further probe this link.

Cue-induced Disruption of Inhibitory Control following Alcohol Consumption

This dissertation provides some of the first evidence is support of a third potential role of attention to alcohol cues in initiating alcohol consumption, and that is via cue-induced disruption of behavioral control. Attention to alcohol stimuli was found to increase behavioral activation and impair inhibitory control, and this could be an important means through which attentional bias operates to promote alcohol

consumption. Moreover, given this evidence of alcohol cue-induced disruption of behavioral control, in conjunction with evidence of a significant attentional bias in heavy drinkers following alcohol (albeit reduced in magnitude), it is important to consider the potential relationships between attentional bias and inhibitory control in intoxicated individuals. This is an important line of inquiry, as acute alcohol impairment of inhibitory control mechanisms has been implicated in promoting excessive, binge-like alcohol consumption (Fillmore, 2003). Specifically, the ability to inhibit or terminate ongoing behaviors is likely integral in the process of terminating a drinking episode, and alcohol impairment of such inhibitory control could compromise the drinker's ability to stop the self-administration of alcohol. Such a theory could explain why many heavy drinkers begin a drinking episode with the intention of only having one or two drinks, but continue on to drink excessively to the point of gross intoxication. The initial couple of drinks could be sufficient to impair the drinker's ability to inhibit the ongoing act of continuing alcohol consumption, resulting in the inability to stop drinking in the situation.

A number of laboratory studies have examined alcohol effects on mechanisms of behavior control, and results have provided remarkably consistent evidence for the acute disinhibiting effects of the drug. Alcohol increases commission errors on go/no-go and continuous performance tasks in a dose dependent manner (e.g., Dougherty et al., 1999; Marczinski & Fillmore, 2003). Additionally, stop-signal tasks show that alcohol produces acute impairments of inhibitory control as evidenced by slower response inhibition and by increased failures to inhibit responses (de Wit, Crean, & Richards, 2000; Fillmore & Vogel-Sprott, 1999). Importantly, there is some initial evidence to suggest an association between alcohol-induced impairment of inhibitory control and heavy alcohol

consumption. For instance, Marczinski et al. (2007) showed that binge drinkers were more sensitive to the disinhibiting effects of the drug, and my masters' thesis demonstrated an association between individual differences in sensitivity to the disinhibiting effects of alcohol and ad lib alcohol consumption (Weafer & Fillmore, 2008). In sum, there is a wealth of evidence showing alcohol's impairing effects on inhibitory control, as well as an association between alcohol-induced disinhibition and excessive consumption.

It is important to note that acute alcohol impairment of inhibitory control occurs in conjunction with the drug's acute rewarding effects. Specifically, an initial dose of alcohol produces increased motivation for further consumption (i.e., the "priming effect") (de Wit & Chutuape, 1993; Fillmore, 2001; Fillmore & Rush, 2001; Ludwig, Wikler, & Stark, 1974), while simultaneously impairing behavioral mechanisms of control, thus decreasing the ability to inhibit this impulse to continue drinking and leading to further, unregulated alcohol consumption. Neuroanatomical evidence regarding acute alcohol effects on dopamine activity in the mesocorticolimbic pathway provides additional support for the interaction of these two mechanisms following acute alcohol consumption. Alcohol increases dopamine release in both the frontal cortex and limbic structures simultaneously, and this is hypothesized to contribute to the drug-induced increase in desire for more alcohol, along with the decrease in the ability to control drinking behavior (Goldstein & Volkow, 2002; Jentsch & Taylor, 1999). Importantly, this reward pathway is the same pathway hypothesized to be activated by alcohol cues. However, to date no research has examined the role of alcohol stimuli in regard to relationships between alcohol-induced disinhibition and incentive reward.

There are reasons to predict that alcohol-induced disruption of inhibitory control might be more pronounced in the presence of alcohol cues. First, alcohol cues are associated with alcohol effects on the reward mechanisms described above for individuals with a highly sensitized incentive-motivation pathway. Both alcohol cues and acute alcohol consumption are thought to increase motivation to drink, as well as increase behavioral activation in pursuit of that goal and impair control mechanisms necessary to inhibit consumption. As such, an additive effect might be observed when acute alcohol effects are measured in the context of alcohol cues, resulting in greater motivation for more alcohol and greater behavioral activation, along with more pronounced disruption of control. A second potential reason for alcohol cues to have a greater effect on behavior in intoxicated individuals is suggested by cue-dependency studies. Previous studies utilizing the cued go/no-go task have shown that individuals are more reliant on cues to guide behavioral control when intoxicated compared to when sober (e.g., Marczinski & Fillmore, 2003, 2005). These studies utilized simple cues that had no intrinsic meaning for participants. It could be that when alcohol stimuli serve as cues, individuals who have conditioned associations to those stimuli might be even more reliant on the cues to guide behavior. This could result in exacerbation of alcohol-induced behavioral activation and impaired inhibition in the context of alcohol cues.

Despite evidence in support of the potential for alcohol-induced disinhibition to be more pronounced in the presence of alcohol cues, it is important to consider findings from Study 1 that showed a decrease in attentional bias in heavy drinkers following alcohol, suggesting that alcohol cues become less salient as blood alcohol concentration increases. As such, the disruptive effect of alcohol cues on inhibitory control observed in

sober individuals could actually be less pronounced following alcohol consumption. However, it is important to distinguish between attentional bias towards alcohol cues (measured by tasks such as the visual probe and SIP), and cue-induced disruption of behavioral control (measured by the ABBA task). For instance, there are notable differences in the role of alcohol stimuli in these types of tasks, as well as fundamental differences in what each task measures. Attentional bias tasks measure the salience of alcohol cues for an individual (i.e., the degree to which one selectively attends to alcohol cues). Alcohol stimuli are presented within the task, and participants are free to look at them as much or as little as they choose. The alcohol stimuli have no meaning in terms of task performance (e.g., the probe replaces alcohol and neutral pictures on an identical number of trials in the visual probe task). As such, these are purely measures of the degree to which an individual selectively prefers to attend to alcohol cues. By contrast, the ABBA task is a direct measure of the influence of alcohol cues on behavior, as the cues provide information that promotes optimal performance on the task. Attention is thus mandated to the stimuli in the ABBA task, allowing for a measure of the degree to which alcohol cues speed behavioral activation and disrupt the ability to inhibit responses. In sum, attentional bias tasks measure the time spent looking at an alcohol cue, whereas the ABBA task measures the subsequent behavioral response to the cue.

Given the distinctions between these two tasks, it does not necessarily follow that an alcohol-induced decrease in attentional bias would imply a corresponding decrease in the magnitude of behavioral response to an alcohol cue. Moreover, it is important to consider that alcohol-related stimuli will continue to be a constant presence in most drinking environments and will still receive some degree of attention. Indeed, the

attentional bias of intoxicated heavy drinkers, while reduced, remained significantly elevated following both active doses in Study 1. Thus even after a drinker's selective attention to the cues diminishes, the cues still have the potential to influence behavior and elicit conditioned responses when encountered. This might be an important means through which alcohol cues can influence drinking behavior in intoxicated individuals, even after the cues have lost some degree of incentive salience.

Implications for Understanding Factors Contributing to Relapse

In addition to adding to the literature regarding factors contributing to excessive alcohol consumption in at-risk young adult drinkers, the findings reported in this dissertation could have particularly significant implications for individuals attempting to abstain from or control their drinking. For instance, attention to alcohol cues encountered in the environment could significantly increase the likelihood of initiation of a drinking episode, despite strong intentions to abstain. Importantly, incentive-sensitization to alcohol stimuli is hypothesized to persist even after long periods of sobriety (Robinson and Berridge, 1993). As such, once an attentional bias is established for an individual, alcohol cues will be expected to continue to hold a pronounced incentive salience and to persist in capturing attention for years, thus contributing to risk of relapse long after initial sobriety is obtained.

The observation of impaired control mechanisms in response to alcohol cues is another important finding that could shed light on processes underlying cue-induced relapse, and as such it will be important for future studies to examine this association in treatment-seeking individuals. It is likely that these individuals might show even greater cue-induced disruption of inhibitory control, given their potential to exhibit both

heightened attentional bias (due to a longer history of excessive alcohol consumption) and impaired inhibitory control mechanisms (due to frontal dysfunction) (Bates, Bowden, & Barry, 2002; Bechara, 2005; Feil et al., 2010; Jentsch & Taylor, 1999; Lyvers, 2000; Parsons & Nixon, 1998). It has long been thought that the lasting changes in frontal lobe functioning produced by chronic heavy alcohol intake contribute to difficulty in controlling or restraining alcohol consumption behaviors, thus putting individuals with a history of alcohol dependence at increased risk for relapse (Crews & Boettiger, 2009; Goldstein & Volkow, 2002; Lyvers, 2000). The current data suggest that the vulnerable behavioral control mechanisms of these individuals could be even further compromised in the presence of alcohol-related stimuli. This produces a difficult scenario for alcohol-dependent individuals attempting to remain sober, in that they must be able to control strong cue-induced urges to consume alcohol, while simultaneously experiencing cue-induced disruption of the inhibitory mechanisms necessary to do so.

Insight into factors underlying relapse potential can provide helpful information to guide treatment strategies aimed at reducing or abstaining from alcohol consumption. Researchers have already begun to investigate the degree to which attentional retraining can successfully decrease both magnitude of attentional bias and subsequent alcohol consumption (Fadardi & Cox, 2009; Schoenmakers et al., 2010), and this is an important first step in applying experimental studies of attentional bias to treatment approaches. The current findings also emphasize the potential for treatment strategies to benefit from incorporating behavioral control training along with such attentional retraining techniques. Specifically, alcohol dependent individuals would likely benefit from information regarding the potential for inhibitory control to be weakened when alcohol

cues are encountered. Additionally, the development of specific strategies to strengthen behavioral control, especially in the presence of alcohol-related cues, could help increase the ability to restrain from alcohol consumption when faced with such cue-induced urges. Further, pharmacotherapy research could benefit from the study of effects of medication on control mechanisms. Research to date has focused heavily on the degree to which medications, such as naltrexone, can reduce motivation for drinking through blunting alcohol-induced reward (Drobes, Anton, Thomas, & Voronin, 2004; O'Malley, Krishnan-Sarin, Farren, Sinha, & Kreek, 2002; Ray & Hutchison, 2007; Tidey et al., 2008). However, there is some emerging evidence for the clinical utility of drugs that also target frontal lobe functioning. For instance, aripiprazole acts on dopaminergic targets in both mesocortical and frontal circuits, and as such has the unique potential to reduce cue- and alcohol-induced motivation to drink, while simultaneously potentiating frontal lobe functioning. Studies have begun to show that aripiprazole has been efficacious in reducing alcohol consumption in both humans (Anton et al., 2008; Kranzler et al., 2008; Warsi, Sattar, Bhatia, & Petty, 2005) and animals (Ingman, Kupila, Hyytia, & Korpi, 2006). Moreover, Voronin et al. (2008) found that aripiprazole led to a reduction in alcohol consumption that was most pronounced in individuals with low self-control. This provides promising evidence regarding the potential for pharmacotherapies to target the interrelated reward mechanisms and control deficits that might predispose alcohol dependent individuals to relapse.

In sum, this dissertation advances the current understanding of the role of attentional bias in heavy alcohol consumption. The studies showed strong associations between attentional bias and multiple alcohol consumption measures, as well as the

potential for alcohol-related stimuli to disrupt mechanisms of behavioral control. It will be important for future studies to examine the degree to which cue-induced disruption of control might be even more pronounced in intoxicated individuals, as well as potential implications such a finding might have for understanding mechanisms underlying unregulated binge drinking. Additionally, future research will benefit from extending the current findings to treatment-seeking individuals to determine if similar patterns are observed. If so, these findings could have important and novel implications for understanding relapse in alcohol-dependent individuals, and could provide information that could potentially guide development of both behavioral and pharmacological therapies for alcohol dependence.

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VITA

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PERSONAL

Place/Date of Birth: Bowling Green, KY; August 12, 1982

EDUCATION

BA, with Distinction, Psychology;
May 2004
Minor in Statistics
Boston University, Boston, MA
Summa Cum Laude, GPA 3.88

RESEARCH EXPERIENCE

University of Kentucky
2009 - 2012
F31 Predoctoral National Research Service Award Fellowship, NIAAA
"Alcohol Sensitivity and Abuse Potential in ADHD"
Mentor: Mark T. Fillmore, Ph.D.

University of Kentucky
2006-2012
Department of Psychology
Graduate Student/Research Assistant
Mentor: Mark T. Fillmore, Ph.D.

Boston University
2004-2006
Department of Psychology
Research Assistant
Mentor: Michael Lyons, Ph.D.

Boston University
2003-2004
Department of Psychology
Independent Work for Distinction
Mentor: Tibor Palfai, Ph.D.

HONORS AND AWARDS

Student Merit Meeting Award
2008-2011
Research Society on Alcoholism
National Institute on Alcohol Abuse and Alcoholism

Graduate Student Achievement Award
2010
Behavioral Neuroscience and Psychopharmacology
University of Kentucky

Travel Award
2010
International Society for Biomedical Research on Alcoholism World Congress
National Institute on Alcohol Abuse and Alcoholism

Guze Meeting Award
2010
Guze Symposium on Alcoholism

Enoch Gordis Award Finalist
2009
Research Society on Alcoholism

Travel Award
2009
International Society for Research on Impulsivity Scientific Meeting

NIDA Predoctoral Research Trainee
2008-2009
Institutional Training Grant (T32; PI: Tom Garrity)
University of Kentucky

Research Challenge Trust Fund Fellow
2007-2008
University of Kentucky

Best Student Poster Award
2007
American Psychological Association Division 28 Convention

Early Career Investigator Award
2007
American Psychological Association
National Institute on Alcohol Abuse and Alcoholism

Graduate School Academic Year Fellowship
2006-2007
University of Kentucky

Phi Beta Kappa
May 2004 -present

University Scholarship
2000 - 2004
Boston University

National Merit Scholars Award
2000 - 2004
Boston University

PUBLICATIONS

Peer Reviewed Manuscripts

Weafer, J., & Fillmore, M. T. (in press). Alcohol-related stimuli reduce inhibitory control of behavior in drinkers. *Psychopharmacology.* PMID: 22358851

Fillmore, M. T., & **Weafer, J**. (in press). Acute tolerance to alcohol in at-risk binge drinkers. *Psychology of Addictive Behaviors.* PMID: 22023021

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Palfai, T. P., & **Weafer, J.** (2006). College student drinking and meaning in the pursuit of life goals. *Psychology of Addictive Behaviors*, 20, 131-134. PMID: 16784355

Fillmore, M. T. & **Weafer, J.** (2004). Alcohol impairment of behavior in men and women. Target Article. *Addiction*, 99, 1237-1246. PMID: 15369556

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Articles

Weafer, J., Milich, R., & Fillmore, M. T. (2008). Driving under the influence of ADHD: Research findings and policy implications. *ADHD Report.*

Book Chapters

Fillmore, M. T., & **Weafer, J.** (in press). Behavioral inhibition and addiction. In J. MacKillop and H. de Wit, (eds.), *The Wiley-Blackwell Handbook of Addiction Psychopharmacology*. West Sussex UK: John Wiley and Sons Limited.

Fillmore, M. T., & **Weafer, J.** (2011). Impaired inhibitory control as a mechanism of drug addiction. In M. T. Bardo, D. H. Fishbein, and R. Milich, (eds.), *Inhibitory Control and Drug Abuse Prevention: From Research to Translation*. New York, NY: Springer Publishing, pp 85-100.

PROFESSIONAL PRESENTATIONS

Oral Presentations

Weafer, J., Miller, M.A., & Fillmore, M.T. (2010). Gender differences in sensitivity to alcohol impairment of simulated driving and behavioral control. In T.R. Butler and **J. Weafer (Chairs)**, Gender/sex differences in alcohol-related behaviors and neuronal injury: A graduate student perspective. Symposium at the International Society for Biomedical Research on Alcoholism World Congress, Paris, France, 2010.

Poster Presentations

Weafer, J., & Fillmore, M.T. (2011). Drinking and driving on the descending limb: A problem of DWI (Driving Without Inhibition)? Poster presented at the annual meeting of the Research Society on Alcoholism, Atlanta, GA.

Weafer, J., & Fillmore, M.T. (2010). Behavioral impulsivity and alcohol consumption in adults with ADHD. Poster presented at the annual meeting of the Research Society on Alcoholism, San Antonio, TX.

Weafer, J., & Fillmore, M.T. (2010). Association between alcohol-induced disinhibition of attention and attentional bias towards alcohol-related stimuli. Poster presented at the annual Guze Symposium on Alcoholism, St. Louis, MO.

Weafer, J., & Fillmore, M.T. (2009). Increased sensitivity to the disinhibiting effects of alcohol in adults with ADHD. Poster presented at the annual meeting of the Research Society on Alcoholism, San Diego, CA.

Miller, M.A., **Weafer, J.**, & Fillmore, M.T. (2009). Gender differences in alcohol impairment of simulated driving and driving-related skills. Poster presented at the annual meeting of the Research Society on Alcoholism, San Diego, CA.

Weafer, J., & Fillmore, M.T. (2008). Alcohol impairment of inhibitory mechanisms: Examining the role of inhibitory control in alcohol abuse. Poster presented at the annual meeting of the Research Society on Alcoholism, Washington D.C.

Weafer, J., Fillmore, M.T., & Milich, R. (2007). Alcohol-induced impairment of driving performance in adults with ADHD. Poster presented at the annual meeting of the American Psychological Association, San Francisco, CA.