THE EFFECTS OF ACUTE PSYCHOSOCIAL STRESS AND ALCOHOL CUES ON INCENTIVE VALUE IN HEAVY DRINKERS

by

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(Under the Direction of James MacKillop)

ABSTRACT

Psychological distress and alcohol cues are commonly-cited antecedents of drinking and relapse. Exposure to both stress and alcohol cues have been shown to increase subjective craving as well as augment value-based decision making. However, the combined effects of stress and craving remain unclear. This study investigated changes in craving and behavioral economic indices of incentive value following a laboratory stress induction and a subsequent alcohol cue exposure in a sample of 84 adult heavy drinkers. Behavioral economic measures included an alcohol purchase task (APT), monetary delayed reward discounting (DDT), and an intertemporal cross-commodity task for alcohol and monetary rewards (AMCP). As hypothesized, stress significantly increased subjective craving and also increased the incentive value of alcohol on the AMCP and APT. Exposure to alcohol cues did not significantly increase incentive value beyond the effects of stress, despite a significant additive increase in subjective craving. Impulsivity on the DDT was not affected by either the stress induction or alcohol cue exposure. Stress-related increases in value on the AMCP were partially mediated by increased demand on the APT. Finally, coping motives moderated the effects of stress on the AMCP such that individuals who

drink to cope showed the greatest change in value following stress. These results converge with prior research that suggests that acute psychosocial stress increases motivation for alcohol; however, this study extends this literature by showing that behavioral economic measures of incentive value also increase under stress. Implications for treatment interventions and existing models of stress-induced drinking and relapse are discussed.

INDEX WORDS: Alcohol, Behavioral economics, Craving, Incentive value, Stress

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DEDICATION

To Laura.

For everything.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Alcohol use disorders (AUDs) are a substantial public health problem, accounting for 80,000 deaths and 4 million accident-related emergency room visits annually (CDC, 2008). Alcohol misuse is the third leading lifestyle-related cause of death in the United States (Mokdad, Marks, Stroup, & Grerberding, 2004) and is associated with a host of health problems, including liver and heart disease, cancer, and an increased risk of sexually transmitted infections from unsafe sex (Corrao, Bagnardi, Zambon, & La Vecchia, 2004; Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994). The social, economic, and legal consequences of alcohol misuse are also profound. For instance, the annual economic burden to society attributed to AUDs is estimated to be in excess of $184 billion (Harwood, 2000).

The development of novel treatments for AUDs as well as the design of effective prevention strategies is contingent on characterizing the biological and psychological factors that underlie these complex disorders. Insights from behavioral science have characterized the external and internal influences that lead individuals to initiate drinking and, in the case of AUDs, develop a clinical disorder. An area of particular focus has been to better understand how impaired decision making contributes substance abuse (e.g., Bechara & Damasio, 2002; Bechara, Dolan, & Hindes, 2002). For instance, Bechara (2005) argued that one fundamental characteristic of addiction is an inability to make choices on the basis of long-term outcomes. This impairment is evident in a

propensity to favor short-term gains and inability to successfully maintain abstinence. In the latter case, despite frequently reporting a preference to remain abstinent, individuals with AUDs often reverse course and resume drinking. Understanding the factors that contribute to these preference reversals and dysregulated decision making in general is a priority for addictions research.

Application of Behavioral Economics to Addiction

Investigating the processes that govern choices between multiple alternatives falls under the purview of behavioral economics, which integrates concepts from psychology and economics to understand how individuals make transactions with their world (Vuchinich & Heather, 2003). This approach has been widely used to understand healthy and unhealthy decision making, especially in the area of addiction (MacKillop, Amlung, Murphy, Acker, & Ray, 2011). Behavioral economics suggests that alcohol misuse is, at its core, a product of repeated choices of short-term positive outcomes from drinking (e.g., subjective intoxication, social facilitation, etc.) at the cost of larger and more temporally-distant gains (e.g., physical health, interpersonal relationships, financial stability, etc.) (Bickel & Marsch, 2001). One particularly relevant behavioral economic concept is incentive value or the specific worth of a commodity to an individual. Incentive value is influenced by a variety of factors, including extrinsic environmental variables and intrinsic motivational states of the individual. For instance, value tends to decrease as the cost of obtaining an outcome increases. Cost may be conferred via increased behavioral cost (e.g., increased effort or responding required to receive an outcome in operant fixed-ratio schedules) or by increasing the literal cost (e.g., price) of the commodity. In behavioral economic terms, this relationship between consumption

and cost is referred to as substance demand (Hursh, Galuska, Winger, & Woods, 2005). The value of an outcome also decreases as the delay to receiving the outcome increases, a concept known as delay discounting. Put simply, $100 available after a short delay (e.g., one day) will typically have greater incentive value than the same $100 that is available after a longer delay (e.g., one year) because the value of the larger reward is discounted over time (Ainslie, 1975; Madden & Bickel, 2009). Both demand and delay discounting have received considerable focus in the addictions literature, and both constructs and their putative relationship with alcohol misuse are discussed in greater detail below.

Behavioral economic demand

Behavioral economic demand reflects how much an individual values a drug or other commodity and is typically quantified through self-administration protocols (Perkins, Ciccocioppo, Jacobs, Doyle, & Caggiula, 2003; Willner, Hardman, & Eaton, 1995) or through hypothetical purchase tasks (Jacobs & Bickel, 1999). Purchase tasks assess estimated drug consumption at escalating levels of price and have been used to assess demand for alcohol (e.g., Murphy & MacKillop, 2006), cigarettes (e.g., Jacobs & Bickel, 1999; MacKillop et al., 2008), and illicit substances (e.g., heroin) (Jacobs & Bickel, 1999). The use of purchase tasks is especially advantageous in addiction studies because this approach circumvents many inherent difficulties involved in self-administration paradigms including high experimental burden, low resolution, and ethical issues (Higgins, Bickel, & Hughes, 1994).

Consumption on purchase tasks is prototypically high at low cost and decreases as cost increases, eventually terminating at zero. Thus, demand tends to be price-insensitive (inelastic) at low costs and increasingly price-sensitive (elastic) at higher costs. Plotting

consumption against price generates a demand curve which can be translated into multiple indices of drug motivation via demand curve analysis. These indices include: Intensity (unrestricted consumption at zero-cost), Breakpoint (the first price at which consumption is completely suppressed), and O_{max} (the maximum expenditure allocated to the drug). Exponential demand curve modeling allows for the calculation of an additional index of Elasticity, an index of proportionate price sensitivity (Hursh & Silberberg, 2008). Though these different indices are theorized to be conceptually related, they are not redundant (Bickel, Marsch, & Carroll, 2000).

Several studies have provided validation of the purchase task approach. First, demand is temporally stable, exhibiting high test-retest reliability (Few, Acker, Murphy, & MacKillop, 2012; Murphy, MacKillop, Skidmore, & Pederson, 2009). Second, performance on a hypothetical alcohol purchase task (APT) has been shown to closely align with performance on an APT for actual alcohol rewards (Amlung, Acker, Stojek, Murphy, & MacKillop, 2012) and, in that same study, self-reported consumption on an APT was highly correlated with actual drinking behavior in a laboratory self-administration protocol. Finally, indices of demand have been found to be associated with validated measures of subjective craving adding further support for using purchase tasks as an objective measure of drug motivation (MacKillop, Miranda, et al., 2010; MacKillop, O'Hagen, et al., 2010).

Individual differences in alcohol demand support the view that AUDs are characterized by overvaluation of alcohol relative to other rewards. Individuals at higher levels of alcohol misuse exhibit significantly higher demand for alcohol (MacKillop, Miranda, et al., 2010; Murphy & MacKillop, 2006; Murphy et al., 2009), and, in

continuous analyses, demand indices are correlated with quantitative measures of alcohol consumption and severity of dependence (MacKillop, Miranda, et al., 2010; MacKillop, O'Hagen, et al., 2010; Murphy & MacKillop, 2006; Murphy et al., 2009). Demand for alcohol also prospectively predicted treatment outcomes following a brief alcohol intervention in college student drinkers (MacKillop & Murphy, 2007). Together, these findings suggest that alcohol demand is sensitive to a variety of meaningful indicators of alcohol misuse and may also have particular promise as a prognostic variable.

Delayed reward discounting

Delayed reward discounting (DRD) measures an individual's preferences for smaller-immediate rewards over larger-later rewards. DRD is typically assessed using intertemporal choice tasks that use a common metric of immediate and delayed rewards, typically money, to systematically assess preferences under controlled conditions (Bickel & Marsch, 2001). For instance, individuals may make choices between various amounts of immediately-available money (e.g., $90, $80, $70, etc.) and a larger alternative reward (e.g., $100) available after several delays (e.g., one day, one week, one month, etc.). An individual's general tendency to prefer the smaller immediate rewards compared to larger delayed rewards (e.g., the temporal discounting rate, or k) is considered a behavioral economic measure of impulsivity (for a comprehensive review, see Madden & Bickel, 2009).

The precipitous devaluation of delayed rewards that characterizes DRD is hypothesized to underlie the repeated loss of control in addictive behavior (Ainslie, 2001; Bickel & Marsch, 2001; Rachlin & Green, 1972). For instance, a meta-analysis of 46 published studies (N = 56,013) found medium-to-large effect size differences between

groups exhibiting addictive behavior compared to matched control groups (MacKillop, Amlung, Few, et al., 2011). With regard to AUDs specifically, steeper discounting of delayed rewards is a consistent finding (Bjork, Hommer, Grant, & Danube, 2004; Boettiger et al., 2007; J. M. Mitchell, Fields, D'Esposito, & Boettiger, 2005; J. M. Mitchell, Tavares, Fields, D'Esposito, & Boettiger, 2007; Vuchinich & Simpson, 1998). Studies also suggest that DRD may be a prognostic indicator of treatment outcomes (Krishnan-Sarin et al., 2007; MacKillop & Kahler, 2009; Sheffer et al., 2012; Tucker, Foushee, & Black, 2008; Tucker, Vuchinich, Black, & Rippens, 2006; Tucker, Vuchinich, & Rippens, 2002; Yoon et al., 2007).

Cross-commodity decision making

Given that one important goal of applying behavioral economics to addictive behavior is to better understand how individuals choose between drugs and other competing rewards, measures that assess choices across multiple commodities may be particularly sensitive to pathological decision making in addiction. These types of cross-commodity choices are common in daily life (i.e., engaging in physical activity versus being sedentary, eating nutrient-rich fruits and vegetables versus high-calorie snacks and desserts). In the same way, individuals with AUDs choose between drinking and achieving the long-term benefits of sobriety. Cross-commodity DRD measures provide one means of assessing these decisions (Bickel et al., 2011; S. H. Mitchell, 2004; Yoon, Higgins, Bradstreet, Badger, & Thomas, 2009). For instance, DRD for immediate cigarettes versus delayed money is increased following acute (Mitchell, 2004) and protracted (Yoon et al., 2009) nicotine deprivation in smokers. Cocaine addicts also show steeper discounting rates for cross-commodity (cocaine vs. money) compared to

exclusively monetary discounting tasks (Bickel et al., 2011). Despite its promise, cross-commodity DRD has not been extensively investigated in alcohol samples.

A related cross-commodity measure, the multiple choice procedure (Griffiths, Troisi, Silverman, & Mumford, 1993), involves dichotomous choices between a fixed amount of a drug and escalating amounts of an alternative monetary reward. This task has been successfully adapted for use in alcohol samples in the form of the alcohol multiple choice procedure (AMCP) (Benson, Little, Henslee, & Correia, 2009; Little & Correia, 2006). Little & Correia (2006) further modified this task to include a delayed money condition in which participants are asked to choose between alcohol available today and a money alternative available after one week. Regardless of the task version used, participants usually prefer the alcohol reward at low monetary amounts, but as the monetary reward increases in magnitude, preferences tend to switch to the money. This crossover point has been shown to be influenced by the amount of alcohol available and the length of the delay associated with the monetary reward (Benson et al., 2009; Little & Correia, 2006). Higher crossover points are also associated with increased weekly alcohol consumption, frequency of binge drinking, and negative consequences from drinking (Little & Correia, 2006).

State-Based Influences on Incentive Value

An ongoing area of research is determining the extent to which behavioral economic variables are trait-like characteristics of individuals (i.e., relatively reliable and stable estimates over time) or whether preferences dynamically fluctuate in response to internal and external influences. The latter view assumes that incentive value is primarily a stable trait, but, in some situations, value can exhibit meaningful state-dependent

qualities. For instance, substance demand is sensitive to experiential states such as drug urge (e.g., MacKillop, O'Hagen, et al., 2010) and acute deprivation (e.g., Griffiths, Rush, & Pauhala, 1996; MacKillop et al., 2012). Similarly, a number of manipulations significantly alter discounting rates. DRD is increased following exposure to sexually arousing stimuli (Wilson & Daly, 2004), sleep deprivation (Reynolds & Schiffbauer, 2004), acute drug administration (e.g., de Wit, Crean, & Richards, 2000; Reynolds, Richards, & de Wit, 2006), and drug withdrawal (Field, Santarcangelo, Sumnall, Goudie, & Cole, 2006; Giordano et al., 2002; S. H. Mitchell, 2004; Yi & Landes, 2012). On the other hand, DRD is significantly decreased by consumption of beverages with high-sugar content (Wang & Dvorak, 2010), working memory training (Bickel, Yi, Landes, Hill, & Baxter, 2010) and cognitive framing effects (Benoit, Gilbert, & Burgess, 2011; Peters & Buchel, 2010). Taken together, these studies suggest that a range of variables can be manipulated to investigate the dynamic properties of incentive value; however, two classes of manipulations are particularly relevant to substance misuse: cue-elicited craving and negative affective states.

Cue-elicited craving

A series of studies have used variations of the standard cue reactivity paradigm to investigate how incentive value is influenced by salient drug stimuli and the experience of subjective craving. Cue reactivity paradigms typically involve exposing individuals to a variety of cues that are associated with the addictive substance and assessing the individuals' reactions (Monti et al., 1987). Commonly, this exposure is multimodal, involving visual, olfactory, tactile, and, in some cases, gustatory cues. The theoretical basis for the relationship between cue reactivity, addiction, and drug use motivation is

strong (for a review, see Drummond, 2000). Loewenstein (1996) proposed that behavior is augmented by a variety of visceral factors, including drug craving, mood, and other emotional states. Exposure to drug-related cues activates these visceral factors that, in turn, have a direct hedonic impact as well as increase incentive value. When these visceral factors reach sufficient intensity, they can augment behavior in a manner that is contrary to long-term self-interest. In a similar vein, the incentive sensitization model (Robinson & Berridge, 2001) suggests that with repeated drug use, the brain systems that are responsible for processing reward and motivation become hypersensitive (sensitized) to the drug. Sensitization is thought to occur via long-term changes in dopamine release and transduction in regions of the mesocorticolimbic dopamine system after repeated drug exposure (e.g., Robinson & Berridge, 2000). Furthermore, Robinson and Berridge suggest that sensitization is not limited to the effects of the drugs themselves, but responses to drug-related cues are also enhanced. Subsequent exposure to these cues activates a psychological process known as incentive salience (i.e., "wanting") that drives drug-seeking and compulsive drug-taking behaviors.

One prediction that stems from these models is that exposure to salient drug cues should directly impact the incentive value of alcohol and other rewards. However, empirical support for this prediction is mixed. Exposure to alcohol cues has been shown to increase demand for alcohol on a hypothetical APT (MacKillop, O'Hagen, et al., 2010). A subsequent study using an actual-outcome APT found trend-level increases in intensity but not other demand indices (Amlung et al., 2012). Findings with measures of impulsivity are similarly mixed. Pathological gamblers have been shown to exhibit significantly greater DRD when assessed in a gambling environment compared to a

neutral environment (Dixon, Jacobs, & Sanders, 2006). However, exposure to a smoking cue environment did not affect DRD in nicotine-dependent individuals (Field, Rush, Cole, & Goudie, 2007). To date, no studies have examined the effects of environmental cues on DRD in alcohol samples.

Negative affect

The second broad category of manipulations that is relevant to alcohol and other drug dependence are negative affect inductions. Negative affect is multidimensional in nature and includes a variety of emotional states, namely depressed mood, anxiety, and distress. Stress is similarly multi-faceted, consisting of affective and physiological states that result from perceiving, interpreting, responding and adapting to challenging or threatening events (Lazarus & Folkman, 1984). Studies in this area have primarily adopted two general approaches to investigating the stress-addiction relationship. First, an individual's overall level of distress in daily life can be quantified and examined in relation to substance misuse. This approach has demonstrated relationships between stress and drinking (e.g. Fox, Bergquist, Peihua, & Rajita, 2010), smoking (e.g. Fields, Leraas, Collins, & Reynolds, 2009), and general substance misuse (e.g. Mooney et al., 2008). For instance, Fox and colleagues (2010) found that an interaction between cumulative life stress and impulsive personality traits accounted for a significant proportion of variance in level of alcohol misuse.

The other approach involves examining responses to an acute stressor in a controlled setting via laboratory stress inductions. A variety of methods exist for inducing stress in the laboratory (Gerin, 2011), though the two most widely used techniques are guided imagery (Sinha, 2013) and social-evaluative performance tests (e.g., the Trier

Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993). Guided imagery involves participants imagining and re-experiencing a stressful life event via an individualized guided imagery script or audio recording. Social-evaluative manipulations such as the TSST, on the other hand, typically require participants to present a speech and/or perform mental arithmetic in front of an audience. Both manipulations have been shown to produce significant increases in self-reported subjective distress, psychophsyiological arousal, and, in most cases, neuroedocrine response (e.g., hypothalamic-pituitary-adrenal (HPA) axis activation) (Dickerson & Kemeny, 2004).

A number of theoretical models of addiction theories emphasize the role of stress in influencing motivation to abuse addictive substances (for a review, see Sinha, 2001). For instance, the stress coping model of addiction (Shiffman, 1982) suggests that individuals use addictive drugs to both reduce negative affect and increase positive affect, making drug use an effective, yet maladaptive, coping strategy (see also Khantzian, 1985; Sher & Levenson, 1982). Sinha's stress-vulnerability model (Sinha, 2001) proposes that abnormal stress responses confer increased vulnerability for addiction. Sinha argues that risk is particularly pronounced for individuals with additional vulnerability factors, including specific personality traits, decreased executive function, genetic predispositions, and family / social influences. At the neuronal level, stress co-activates brain circuits responsible for processing rewards and inhibitory control (see Li & Sinha, 2008), providing a common neural system by which stress may exacerbate drug misuse. This overlapping circuitry is also central to the homeostatic dysregulation / allostasis model of addiction proposed by Koob and Le Moal (1997, 2001). In their view, repeated exposure to stress produces neuronal changes in brain reward circuits that lead to

heightened sensitivity to the reinforcing properties of addictive drugs. In effect, stress is thought to "prime" brain reward systems by enhancing the relative reinforcing efficacy of addictive substances and, subsequently, increasing motivation to compulsively use those substances (Piazza and Le Moal, 1998).

Preclinical and clinical research investigating the link between stress and addiction has increased substantially in the past two decades, particularly in the case of studies using acute negative affect manipulations. In the case of demand, preliminary data suggests that a guided imagery stress induction significantly increases demand for alcohol on an APT (MacKillop & Ray, 2011). This finding is particularly important in light of mixed findings with regard to increased subjective motivation for alcohol after stress induction. While some studies have found that acute stress increases self-reported alcohol craving (Field & Powell, 2007; Fox, Bergquist, Hong, & Sinha, 2007) and alcohol consumption (e.g., de Wit, Soderpalm, Nikolayev, & Young, 2003; Kidorf & Lang, 1999; Nesic & Duka, 2006; Soderpalm Gordh, Brkic, & Soderpalm, 2011; Thomas, Bacon, Randall, Brady, & See, 2011), others have reported null findings (Pratt & Davidson, 2009; Thomas, Randall, Brady, See, & Drobes, 2011). Using more objective indices of craving from purchase tasks, therefore, may be sensitive to potentially meaningful aspects of the stress response that are not captured by subjective measures of drug urge.

By comparison, a larger number of studies have examined the relationship between acute stress and impulsivity. In healthy participants, acute stress or negative mood inductions have been found to bias decisions toward immediate rewards (Flora, Wilkerson, & Flora, 2003; Gray, 1999; Knapp & Clark, 1991; Tice, Bratslavsky, &

Baumeister, 2001), increase risk taking (Lighthall, Mather, & Gorlick, 2009; Porcelli & Delgado, 2009; Starcke, Wolf, Markowitsch, & Brand, 2008; van den Bos, Harteveld, & Stoop, 2009), and disrupt goal-directed decision making (Schwabe & Wolf, 2009). To date, only two studies have investigated the effects of acute stress on DRD with mixed findings. White et al. (2008) reported that DRD was not affected by an acute stressor in healthy individuals; however, stress did shorten decision times on impulsive choices for a subset of participants, which may be reflective of increased behavioral impulsivity. Lempert et al. (2012) later found increased impulsive DRD following acute stress, but only in those individuals with low trait perceived stress. Research with substance misuse samples, however, is notably lacking. In one case, an acute stressor was found to interfere with stop signal test performance in problem drinkers (Zack et al., 2011) with similar inhibitory deficits observed in adolescent smokers (Schepis, McFetridge, Chaplin, Sinha, & Krishnan-Sarin, 2011). Counter to these findings, acute stress did not affect go/no-go performance in an opioid-dependent sample (Constantinou et al., 2010).

In the domain of cross-commodity decision making, Rousseau et al. (2011) recently found that crossover points on an AMCP task were significantly higher after a negative mood induction in social drinkers who reported drinking to cope with negative affect. Coping motives have also been cited as important individual differences variables in studies of negative mood-induced craving (e.g., Birch et al., 2004) and stress-induced changes in attentional bias for alcohol-related cues (e.g., Field & Powell, 2007; Field & Quigley, 2009). Importantly, the Rousseau et al. study used a general negative mood induction and not a stress induction and their AMCP only assessed immediately-available rewards. An interesting question that arises from their study, therefore, is whether similar

effects would be found following a laboratory stress manipulation or if the AMCP measure assessed immediate versus delayed rewards.

Priorities for Research

The extant literature suggests that a number of behavioral economic measures of incentive value have both trait-like and state-like properties. Studying the effects of cue-elicited craving and acute stress has promise for clarifying how these processes interact to augment value-based decision making and, ultimately, their contribution to alcohol misuse. However, since the number of studies in this area is relatively modest with much of the research in healthy individuals, several important empirical questions remain to be tested.

First, though previous research supports the notion that incentive value can be influenced by a variety of intrinsic and extrinsic factors, precisely which measures of value are the most sensitive is an open question. To date, studies examining state effects on incentive value have focused individually on demand, DRD or cross-commodity choices, but no studies have looked at the confluence of these measures. Examining multiple measures of incentive value may be better suited to disentangle which aspects of value are most affected. Including multiple measures also allows for examination of mediation effects between the individual indices. For instance, it is entirely plausible that changes in cross-commodity preferences may be mediated, in part, by increases in demand for alcohol or increased DRD.

Second, since decisions to use drugs often occur in a specific behavioral context (such as high arousal states following exposure to acute stress or drug-related stimuli), it is of great relevance to examine changes in choice behavior in these situations (Li and

Sinha, 2008). However, the majority of previous studies have investigated cue-elicited craving and stress separately even though they often occur concurrently. Individuals with AUDs may experience a particularly distressing event—such as a conflict with a friend or spouse or a poor evaluation at work—and then, a short time later, encounter salient alcohol cues (i.e., driving past a bar or liquor store). At this point, the individuals must decide whether to drink and obtain the short-term positive outcomes from doing so or not to drink in favor of the long-term gains from continued sobriety. To this end, a limited number of studies have examined the ability of stress to potentiate cue-elicited craving and the results have been equivocal. Some studies have found that the effects of acute stress and cue exposure are additive (Coffey et al., 2002; Cooney, Litt, Morse, Bauer, & Gaupp, 1997; Liu & Weiss, 2002) and are also predictive of relapse in alcoholics (Cooney et al., 1997), yet other studies have found no enhancement (McRae-Clark et al., 2011; Ray, 2011; Thomas, Randall, et al., 2011). Mixed findings in this area may be attributed, in part, to incomplete assessment of all facets of the craving experience. Including behavioral economic measures of value for alcohol is one means of addressing this potential limitation (e.g., MacKillop and Ray, 2011).

Aims and Hypotheses

The purpose of this study was to investigate the combined effects of acute psychosocial stress and alcohol cues on behavioral economic measures of incentive value in heavy drinkers. This study examined behavioral economic decision making both before and after a validated laboratory stress induction procedure and examined differences based subsequent exposure to either alcohol or neutral cues. This study had two Primary Aims and two Secondary Aims:

Primary Aim #1: Examine the impact of an acute laboratory stress induction on three measures of incentive value – an AMCP for actual alcohol and monetary rewards, a hypothetical APT, and a hypothetical monetary DRD task.

Hypotheses: Exposure to an acute stressor was expected to increase the incentive value of alcohol. This would be evident in significantly higher crossover points on the AMCP and greater demand for alcohol on the APT. Stress was also expected to increase the rate of DRD (i.e., increase impulsive decision making).

Primary Aim #2: Examine the impact of a subsequent alcohol or neutral cue exposure following the stress induction on the same measures of incentive value.

Hypotheses: Subsequent exposure to alcohol cues, but not neutral cues, was predicted to further increase incentive value, evident in higher AMCP crossover points, greater demand, and steeper DRD compared to post-stress performance.

Secondary Aim #1: Examine the interrelationships between the measures of incentive value to determine whether the effects of stress or cues on one measure are mediated by effects on the other measures.

Hypotheses: State effects on the cross commodity measure (AMCP) may be partially mediated by the effects on the APT and DRD task. In other words, increased value of alcohol on the AMCP may be a function of increased demand and greater discounting.

Secondary Aim #2: Examine potential moderators of stress and cue effects on incentive value, including: gender, alcohol problem severity, and coping motives for drinking.

Hypotheses: Consistent with past research on the role of coping motives in state-based fluctuations in AMCP performance (e.g., Rousseau et al., 2011), stress effects on incentive value were predicted to be greatest in those individuals who endorse coping as a main motive for drinking. The other moderators were exploratory, so no specific directional hypotheses were made for these variables.

CHAPTER 2

METHOD

Experimental Design

This study employed a two-group, repeated measures design with successive within-subjects and between-subjects manipulations. All participants underwent the laboratory stress induction (within-subjects manipulation). Participants were then randomly assigned to one of two cue exposure conditions: alcohol cues or neutral cues (between-subjects manipulation). Block randomization was used to assign equal numbers of participants by gender to the two cue conditions.

Participants

Participants (N = 90) were recruited from the Athens, GA, community via advertisements soliciting regular drinkers for an alcohol research study. Inclusion criteria were: 1) Age 21-45; 2) Current heavy drinking (i.e., greater than fourteen standard drinks per week for males and seven standard drinks for females (NIAAA, 2010); 3) Computer fluency (using a personal computer at least four days per week) to ensure adequate competency with computerized assessments. Exclusion criteria were: 1) Actively seeking treatment for alcohol problems or having undergone treatment in the past ninety days; 2) Currently taking any psychotropic medication or other medication that may affect response to alcohol; 3) Current diagnosis or treatment for co-morbid DSM-IV Axis I psychiatric conditions or report of psychotic symptoms during last six months; 4) Attending laboratory sessions under the influence of alcohol (breath alcohol level (BrAC)

> 0.00g%); and 5) Current pregnancy or breastfeeding (females only). Of the total sample, one participant was excluded for low effort (i.e., non-compliance with stress induction and cue exposure instructions), one participant was excluded due to a conflicting obligation after the session that was revealed during debriefing (i.e., a class study group that prevented any possibility of drinking during the session), and four additional participants were excluded due to ceiling or floor effects on the primary AMCP measure (i.e., either all alcohol choices or all money choices), resulting in a final *N* of 84. Sample characteristics are provided in Table 1.

Assessment

Demographics. Participants completed a comprehensive demographics assessment that included sex, race, ethnicity, income, and other descriptive variables.

Alcohol use measures. Alcohol consumption was assessed using the 28-day Timeline Follow-Back (TLFB) procedure (Sobell & Sobell, 1992). The Alcohol Use Disorders Identification Test (AUDIT) (Saunders, Aasland, Babor, de la Fuente, & Grant, 1993) served as an index of alcohol misuse. BrAC was measured using a breathalyzer system (Intoximeters, Inc; St Louis, MO).

Stress and cue reactivity. Participants rated their subjective state using a series of 10-point visual analogue scales (VAS) that assessed the following items: craving for alcohol (4 items), stress, nervousness, relaxation, calmness, happiness, and sadness. The four craving items were subsequently averaged into one composite craving score (Cronbach's $\alpha = .96$, individual item intercorrelations (*r*s) = .73-.94). Objective measures of psychophysiological arousal included heart rate (HR) and mean arterial pressure

(MAP), both measured using an electronic wrist blood pressure cuff (Welch Allyn, Inc.; Skaneateles Falls, NY).

Alcohol multiple choice procedure. The primary behavioral economic measure was an intertemporal cross-commodity decision-making task (AMCP; Little & Correia, 2006) that consisted of choices between immediate alcohol and delayed monetary rewards. The AMCP allowed for concurrent examination of delay (i.e., DRD) and cost (i.e., demand), thereby providing a close proxy for cross-commodity choices made in the natural environment. Participants made choices between a single standard-sized drink of the participants' preferred alcoholic beverage that was available today and eighteen amounts of money ($0.01, $0.10, $0.50, $1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $11, $12, $13, $14, and $15) that were available after a one week delay. Individual items were randomized to prevent explicit reference points provided by sequential assessment (e.g., Amlung & Mackillop, 2012). The AMCP also directly determined the outcome received during the self-administration period: participants were told that they would receive the alcohol or money associated with one of their choices on the AMCP, selected at random (see Procedure).

Alcohol purchase task. Participants completed a hypothetical APT that was based on previous studies using state-based purchase task assessments (Amlung et al., 2012; MacKillop, O'Hagen, et al., 2010). Participants were asked how many alcoholic beverages they would consume at eighteen different prices ranging from $0.01 to $15 per drink, presented in a randomized order. For maximum symmetry across measures, APT price intervals were identical to the monetary amounts on the AMCP. Although the APT was hypothetical, participants were instructed to make their best estimates of how many

drinks they would consume as if they would actually receive the alcohol (e.g., Amlung et al., 2012).

Delayed reward discounting. Delay discounting was assessed using a multi-item delay discounting task (DDT) consisting of choices between hypothetical smaller-immediate and larger-delayed monetary rewards. Again, for the purposes of homology across measures, the larger-delayed reward was $15 available after 1 week and the smaller-immediate rewards were identical to the AMCP monetary amounts (with the exception of $15) and were available today. Altogether, a total of 17 discounting trials were presented in a randomized sequence. Although the DDT was shorter than most DRD paradigms used in prior research (Bickel, Pitcock, Yi, & Angtuaco, 2009), the duration of the discounting assessment was purposely kept short to permit investigation of state effects that may be relatively brief in temporal duration. Prior to completing the DDT participants were instructed to choose which amount they would prefer as if all outcomes are guaranteed (e.g., Bickel et al., 2009; Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003).

Individual differences measures. Participants also completed a battery of individual differences measures for secondary analyses. The Drinking Motives Questionnaire-Revised (DMQ-R) (Cooper, 1994) was used to assess common motives for drinking alcoholic beverages including drinking to cope with negative affect.

Procedure

Prospective participants were initially screened via a brief telephone interview. Participants who met enrollment criteria were then invited to the laboratory for a single in-person laboratory session lasting approximately 4.5 hours (see Figure 1 for a

schematic of session components). Sessions were scheduled the afternoons or early evenings for correspondence with typical drinking hours and took place on days identified by the participants as having no conflicting factors that might affect choices to drink. Upon arriving at the laboratory, participants provided written informed consent, sobriety was confirmed via breathalyzer, age was verified by state-issued photo ID, and female participants took an over-the-counter pregnancy test. Participants were then given an overview of the session procedures, including policies concerning the consumption and recovery periods. This overview also included explicit instructions regarding which tasks were for real versus hypothetical rewards. After ensuring that participants fully understood the parameters of the session, the alcohol interview and individual differences measures were administered.

Participants then completed a ten-minute relaxation period during which they sat in a neutral laboratory room while listening to soothing music and reading a variety of popular magazines. Inclusion of a relaxation period is a standard practice in laboratory stress paradigms in order to provide a valid baseline phase for the acute stress induction (Gerin, 2010). After the relaxation period ended, participants completed the first of three primary assessments (Baseline) that consisted of the AMCP, DDT, APT, subjective ratings, and HR/MAP.

Participants then underwent the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), an acute psychosocial stress induction that has consistently shown to be very effective in inducing psychological distress and increases in neuroendocrine stress response (e.g., Dickerson & Kemeny, 2004). The TSST lasted fifteen minutes and consisted of three phases: preparation, public speaking, and mental arithmetic.

Specifically, participants were given five minutes to prepare a brief speech on "*why they should be hired for a dream job."* They were told that their speech would be given in front of a small hiring committee and that their performance would be video recorded for later analysis. Participants were provided with paper and pencil for preparation purposes and a countdown timer set to five minutes was placed on the table. After five minutes elapsed, participants were escorted to a laboratory conference room where three committee members (confederates) in white laboratory coats were seated and a video camera mounted on a tripod was pointed towards the participants (see Figure 2A). To minimize the potential effects of confederate gender, the panel was comprised of at least one male and one female confederate (Gerin, 2011). Participants were instructed to begin their speech, and after each pause of greater than ten seconds, they were prompted to continue until the five minutes was finished. After the public speaking phase ended, the participants completed a mental arithmetic test that consisted of counting backwards out loud from 1,022 to 0 in units of 13. After each incorrect response, participants were instructed to begin again at 1,022. After five minutes of mental math, the experimenter returned and escorted the participants to the original testing room to complete the second assessment (Post-Stress) consisting of the AMCP, DDT, APT, subjective ratings, and HR/MAP.

Participants next underwent a multimodal cue exposure based on established procedures (Amlung et al., 2012; MacKillop, O'Hagen, et al., 2010; Monti et al., 1987). Participants were randomly assigned to either the alcohol or neutral cues condition. The procedures were identical in both conditions, with the exception of the physical environment and beverage used. Alcohol cues included a simulated bar laboratory,

consisting of a bar, alcohol-related decorations, representative bottles of alcohol, and the participants' preferred alcoholic beverage (Figure 2B). Neutral cues included a standard laboratory testing room with neutral décor and a bottle of spring water (Figure 2C). In both conditions, participants listened to a standardized audio recording that directed the multisensory cue exposure (i.e., viewing and handling the beverage, intermittent inhalation of the smell of the beverage, and taking a small sip of the beverage). The total duration of the cue exposure was fifteen minutes. Following the cue exposure, participants completed the third assessment (Post-Cues) consisting of the AMCP, DDT, APT, subjective ratings, and HR/MAP.

Actual outcomes from the AMCP were based on receipt of one-randomly selected choice from the three administrations of the AMCP (Baseline, Post-Stress, Post-Cues). Immediately following the Post-Cues assessment, participants selected a poker chip from a fish bowl containing chips pertaining to the individual item numbers from all AMCP choices (e.g., Amlung et al., 2012). If the participant's choice was for alcohol, they received a fresh beverage at that moment. If their choice was for the delayed money, participants were told that they would be given their money after the 1-week delay had elapsed. Regardless of the outcome selected, all participants were required to remain in their respective exposure rooms for a 15-minute consumption period. Participants who received alcohol were permitted to drink *ad libitum* during this time. A bottle of water was provided as an alternative beverage to control for general thirst and participants were provided with a variety of reading materials.

After the consumption period, all participants completed a 60-minute recovery period in a neutral laboratory lounge. Participants were provided with light refreshments

and given access to their personal belongings. BrAC measurements and other assessments were collected at periodic intervals. At the end of the recovery period, participants underwent a debriefing interview and, if their BrAC was <0.04g% (NIAAA, 2005), they were dismissed. Participants received $40 in cash for participation and up to $15 in additional compensation from the AMCP (56% of participants received money from the AMCP; average reward = $9.14). All procedures were approved by the University of Georgia Institutional Review Board.

Data Analysis

Power analysis. A power analysis was conducted using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) for the least powerful primary hypothesis—that exposure to alcohol cues would significantly increase AMCP crossover points relative to neutral cue exposure. Power was calculated for a mixed ANOVA with cue type as a two-level between-subjects variable and time as a two-level within-subjects variable. A medium effect size (*f*) of 0.30 was anticipated based on previous alcohol cue reactivity studies (e.g., Carter & Tiffany, 1999) and the recent study by Rousseau et al. (2011) that found a medium effect size increase (f = 0.31) in AMCP crossover points following a negative affect induction. Assuming an α of 0.05, the current sample size of 84 had an expected power (β) of 0.88 to detect a medium-sized effect (f = 0.30). This sample size was also optimally powered for the within-subjects analysis of stress induction effects (β > 0.99).

Preliminary analyses. All variables were initially screened for missing data, outliers (Zs > 3.29), and distribution abnormalities (Tabachnick & Fidell, 2001). Outlying values that were determined to be legitimate responses were replaced with the next

highest non-outlying value. Variables that were significantly skewed or non-kurtotic were transformed using logarithmic or square root transformations.

The primary dependent variable from the AMCP was the crossover point, the price at which the participants' preferences switched from the alcohol reward to the monetary reward. Crossover points were calculated as the mean of the last price that alcohol was chosen and the first choice that the money option was chosen. If no clear crossover point could be identified due to inconsistent responding, an iterative process was employed to identify the most consistent crossover price from the pool of potential values. Indices of alcohol demand from the APT were generated using a data-driven observed values approach (Murphy & MacKillop, 2006) and a model-driven derived values approach using demand curve modeling (Hursh & Silberberg, 2008). Intensity of demand was operationalized as consumption when drinks were \$0.01 (minimum cost); Breakpoint was operationalized as the first price that consumption was completely suppressed; and O_{max} was operationalized as the maximum alcohol expenditure. Finally, Elasticity was derived using the following nonlinear exponential demand curve model (Hursh & Silberberg, 2008):

$$\log_{10} Q := \log_{10} Q_0 + k\,(e^{-\alpha P} - 1) \qquad (1)$$

where Q = quantity consumed, Q_0 = derived intensity, k = the range of the dependent variable (standard drinks) in logarithmic units, and α = Elasticity (rate constant determining the rate of decline in log consumption based on increases in price). The overall mean performance across all three APT assessments was first analyzed to obtain the best-fitting k parameter, which was determined to be 3.0 and used for all individual demand curves. For the DDT, delay discounting was quantified using an impulsive

choice ratio (ICR), or the proportion of choices for the small-immediate reward (e.g., Ainslie & Monterosso, 2003; J. M. Mitchell et al., 2005). This is a common index of temporal discounting and has the advantage of no quantitative assumptions.

Primary and secondary analyses. A series of manipulation checks was conducted to verify the effects of the acute stress induction and cue exposure. Specifically, repeated measures ANOVAs were used to confirm the anticipated changes in subjective ratings (i.e., craving and affect) and physiological arousal (i.e., HR/MAP) following the stress induction (from Baseline to Post-Stress) and the cue exposure (from Post-Stress to Post-Cues). Primary analyses were conducted to test the hypotheses for each of the study's two primary aims. The effects of acute stress were examined using a series of repeated measures ANOVAs for each behavioral economic variable with time as a two-level within-subjects factor (Baseline to Post-Stress). The effects of exposure to alcohol or neutral cues were examined using a series of mixed ANOVAs for each variable with time as a two-level within-subjects factor (Post-Stress to Post-Cues) and condition as a two-level between subjects factor (Alcohol vs. Neutral).

Interrelationships between the measures of incentive value were examined to determine whether the effects of stress or cues on the AMCP were mediated by changes in DRD or demand for alcohol. Specifically, mediation analyses were conducted with ordinary least squares regression using procedures recommended for examining mediation in within-subjects data (Judd, Kenny, & McClelland, 2001). According to Judd et al., mediation exists if two conditions are met: (1) the mediator variable shows a significant effect across time that is in the same direction as the effect for the criterion variable, and (2) the change in the mediator variable predicts the change in the criterion

variable. In these analyses, the criterion variable was the change in AMCP crossover points from one time point to the next. This difference score was regressed onto both the sum (mean-centered) and the difference score between the two time points for the mediator (Judd et al. 2001). The portion of the mean treatment effect on AMCP crossover points not mediated through the mediator variable (i.e., the magnitude of the treatment difference in AMCP, over and above mediation) was estimated by examining the significance of the intercept in the regression model (e.g., Judd et al. 2001). Separate regression analyses were conducted for each potential mediator that showed a significant main effect of time/condition (i.e., meeting condition 1 of Judd et al., 2001)

Several potential moderators of stress and cue effects on incentive value were also investigated, including sex, alcohol problem severity (e.g., AUDIT), and coping motives. For continuous variables (AUDIT, coping motives), a dichotomous variable was generated corresponding to the upper and lower quartiles on the respective measures. Moderation was investigated by repeating each of the primary ANOVAs with the addition of the moderator variable as a between-subjects factor. A statistically-significant time x group interaction was taken to indicate moderation.

A conventional significance level of $p < .05$ was be used for all analyses and effect sizes (r and η_p^2) were generated. All analyses were conducted using SPSS Version 20 (IBM; Armonk, NY) and GraphPad Prism (GraphPad Software, Inc.; La Jolla, CA).

CHAPTER 3

RESULTS

Preliminary Analyses

All variables were initially screened for missing data, outliers, and distribution abnormalities. No missing data were present for any of the variables. A small number of outliers were present for the behavioral economic indices (0.3% of all data points), and after determining that these values were legitimate responses, the values were re-coded as one unit higher than the next non-outlying value (Tabachnick & Fidell, 2001). Demand indices on the APT were positively skewed, so square root transformations were applied to Intensity, Breakpoint, and O_{max} and logarithmic transformations were applied to Elasticity. These transformations resulted in non-significant levels of skewness and kurtosis (Zs < 2.6). The exponential demand curve equation (Hursh & Silberberg, 2008) provided a good fit to the APT data across all assessments (median R^2 = .84, inter-quartile range = .78-.89). Relative to female participants, males consumed significantly more drinks / week, [Male: *M* = 20.36, *SD* = 9.50; Female: *M* = 11.70, *SD* = 5.72; *t*(81) = 5.02, *p*<.001], and also had significantly higher AUDIT scores [Male: *M* = 11.90, *SD* = 4.06; Female: *M* = 9.00, *SD* = 4.78; *t*(81) = 3.00, *p*<.01]. No gender differences were present for any of the other demographic variables. Alcohol and neutral cues groups did not significantly differ on any demographic or alcohol variables (*p*s > .39).

A series of manipulation checks was performed to confirm the effects of the stress induction and cue exposure. Following the acute stress induction, participants reported

significantly greater craving for alcohol ($p < .05$) along with significantly greater stress, nervousness, and sadness (ps <.01) and significantly lower relaxation, calmness, and happiness (ps <.01) (Table 2). Significant increases were also observed for the objective measures of stress, including increased MAP and elevated HR (ps < .001; Table 2). Together, these results support the validity of the acute stress induction procedure. With regard to the cue exposure, a significant Time x Condition interaction ($p < .001$) was found for subjective craving indicating that exposure to alcohol cues but not neutral cues significantly increased craving for alcohol (Table 3). HR similarly increased following exposure to alcohol cues and decreased following exposure to neutral cues ($p <. 01$) (Table 3). All other affect items (except sadness) and MAP significantly decreased from Post-Stress to Post-Cues (ps < .01), indicating that the acute of effects of the stress induction on these variables diminished over time regardless of the cue environment encountered (Table 3).

Primary Analyses

Effects of stress on incentive value. Repeated measures ANOVAs were used to examine the effects of the acute stress induction on each of the indices of incentive value (Table 4). Participants exhibited significantly higher crossover points on the AMCP following stress ($p < .05$; Figure 3A). Significantly higher demand for alcohol was also evident for Intensity ($p < .05$; Figure 3C), Breakpoint ($p < .01$; Figure 3D) and O_{max} ($p <$ .01; Figure 3E). Elasticity did not differ between Baseline and Post-Stress ($p = .18$; Figure 3F). Finally, ICR decreased after the stress induction, although this difference was only marginally significant ($p = .08$; Figure 3B).

Effects of alcohol cues on incentive value. The effects of the cue exposure on incentive value were examined using a series of mixed ANOVAs (see Table 5). In this case, the primary effect of interest was the time x condition interaction that reflected significant increases in value following exposure to alcohol but not neutral cues. The only variable to show this pattern was Breakpoint which increased very modestly following exposure to alcohol cues and decreased following exposure to neutral cues ($p < .05$). A trend-level interaction was also present for O_{max} ($p = .08$) which decreased from Post-Stress to Post-Cues for both groups, but did so to a greater extent for the neutral cues group. In both conditions, AMCP crossover point, intensity, and O_{max} significantly decreased from Post-Stress to Post-Cues (ps $< .01$). No significant main effects of cue condition were found for any variable (ps $> .10$). ICR was not significantly affected by the cue exposure (ps $> .18$).

Secondary Analyses

Mediators of stress and cue effects. Mediation analyses (Judd et al., 2001) were conducted to examine whether stress-related increases in AMCP crossover points were mediated by changes in either DRD or alcohol demand. Three indices met Judd et al.'s first condition for mediation (i.e., the potential mediator variable should show a statistically significant effect across time that is in the same direction as the AMCP effect): O_{max}, Breakpoint, and Intensity. The results of the regression analyses for each of these indices are presented in Table 7. If mediation exists, the difference in the mediator variable across time should predict the difference in the criterion variable in a multiple regression model that also includes the sum of the mediator across time (Judd et al. 2001). The only index to show this effect was O_{max}, $\beta = .23$, $t(81) = 2.11$, $p = .04$.

Furthermore, the intercept of this model (i.e., the non-mediated portion of the AMCP effect) was not statistically-significant (p = .10) but also was not reduced to zero indicating that the increase in AMCP crossover points from Baseline to Post-Stress was partially mediated by increased O_{max}. A trend-level effect was observed for Breakpoint, β = .21, $t(81)$ = 1.90, p = .06, and the non-mediated portion of this model was similarly non-significant (p = .08) indicating that changes in Breakpoint may also partially mediate changes in AMCP. However, Breakpoint and O_{max} were highly correlated across assessments (Baseline: r = .84, p < .001; Post-Stress: r = .90, p < .001) suggesting that these indices were capturing overlapping aspects of incentive value. Changes in Intensity did not significantly mediate stress-induced changes in AMCP. With regard to the cue exposure effects, since AMCP crossover points did not differ as a function of cue condition (i.e., Judd et al.'s first criterion for mediation was not met), mediation analyses were not performed for the cue exposure portion of this study.

Moderators of stress and cue effects. Several potential secondary variables were examined as potential moderators of stress and cue effects, including coping motives, severity of alcohol use and misuse, and gender (see Table 8). Moderation was operationalized as a significant moderator x time interaction in a repeated measures ANOVA. The only variable to show such a pattern was coping motives as a moderator of stress-induced increases in AMCP crossover point. As depicted in Figure 4, those individuals who were in the high coping motives group (i.e., the upper quartile on the coping subscale of the DMQ) reported significantly higher crossover points following stress while those individuals in the lower quartile did not. Moderation by coping motives was confirmed using a linear regression approach that included DMQ coping score as a

continuous predictor variable of change in AMCP crossover point in the entire sample (e.g., Judd et al., 2001). In this analysis, coping motives accounted for a significant proportion of the variance in ACMP crossover points, $R^2 = .05$, $F(1, 83) = 3.96$, $p < .05$, and also significantly moderated the change in AMCP from Baseline to Post-Stress, $\beta = .22$, $t(82) = 1.99$, $p < .05$. Neither gender nor AUDIT moderated stress effects on any of the behavioral economic indices in the ANOVA analyses (*p*s > .45). Similarly, AUDIT did not moderate stress effects using a linear regression approach that treated AUDIT continuously ($p > .78$).

The same secondary variables were also investigated as potential moderators of cue exposure effects. In the case of AUDIT scores, trend-level moderation effects were found for intensity ($p = .07$) and ICR ($p = .06$). For intensity, individuals in the high AUDIT group tended to show a more robust increase in intensity following alcohol cue exposure whereas the individuals in the low AUDIT group tended to show a more robust decrease in intensity following neutral cue exposure (see Table 9). For ICR, exposure to alcohol cues did not significantly affect impulsive choices in the high AUDIT group; however, exposure to alcohol cues resulted in a 4% increase in impulsive choices in the low AUDIT group (see Table 9). AUDIT did was a not a significant moderator of any of the other indices (*p*s > .30). Finally, neither coping motives (*p*s > .30) nor gender (*p*s > .15) significantly moderated changes in value from Post-Stress to Post-Cues.

Interrelationships between behavioral economic indices. Interrelationships between the indices of incentive value at each time point were examined using Pearson's correlations (see Table 6). Statistically significant correlations were found between AMCP crossover point and each of the other variables at each time point (*r*s .23-.48, *p*s <

.05). Consistent with prior research (Amlung et al., 2012; MacKillop, Miranda, et al., 2010), correlations among demand indices ranged from moderate to high (*r*s .35-.97, *p*s < .01). Finally, ICR showed mixed associations with the other indices, including moderate associations with AMCP crossover point across all three assessments (*r*s .32-.40, *p*s < .01).

CHAPTER 4

DISCUSSION

The primary goal of this study was to investigate the effects of acute psychosocial stress and alcohol-related environmental cues on behavioral economic measures of incentive value. Heavy-drinking adults underwent a validated laboratory stress induction and were subsequently exposed to stimuli associated with alcoholic or neutral beverages. Primary outcome measures included multiple behavioral economic measures of incentive value, including demand for alcohol (APT), impulsive choice (DDT) and an intertemporal cross-commodity decision-making task (AMCP). Secondary goals of this study included investigating interrelationships among the behavioral economic variables to probe for mediation effects as well as investigating several candidate moderators of stress and cue effects. Manipulation checks supported the validity of both the TSST and the cue exposure, indicating that the stress and craving manipulations had the intended effects on participants' mood and physiological state. As hypothesized, stress significantly increased subjective craving and also increased the relative value of alcohol on the AMCP and several demand indices from the APT (Intensity, Breakpoint, and O_{max}). Counter to predictions, exposure to alcohol cues did not significantly increase incentive value beyond the effects of stress, despite a significant increase in subjective craving. Impulsivity was not affected by either the stress induction or alcohol cue exposure. Stress-related increases in AMCP crossover points were partially mediated by increased demand for alcohol (O_{max}). Finally, coping motives moderated the increase in

AMCP crossover points such that individuals who drink to cope with negative affect showed the largest increase in value for alcohol after stress.

The primary results from this study replicate previous research and extend the literature in several important ways. First, the finding that subjective craving significantly increased following the acute stress induction is consistent with prior studies that reported stress-related increases in alcohol motivation (de Wit et al., 2003; Field & Powell, 2007; Fox et al., 2007; Kidorf & Lang, 1999; Nesic & Duka, 2006; Soderpalm Gordh et al., 2011). However, this study expands the literature by showing that objective measures of alcohol motivation (i.e., the AMCP and APT) are also enhanced by stress. In fact, the effect sizes for some of the behavioral economic indices (AMCP crossover point, Breakpoint, and O_{max}) were larger than for the subjective craving ratings. This is notable since previous laboratory studies that have reported significant state-level increases in behavioral economic measures of value have typically found these effects to be of smaller magnitude relative to craving ratings (e.g., Amlung et al., 2012; MacKillop et al., 2012; MacKillop, O'Hagen, et al., 2010; MacKillop & Ray, 2011). This finding is also particularly relevant in the context of prior research that failed to find significant increases in craving under stress (Pratt & Davidson, 2009; Thomas, Randall, et al., 2011). These results support the notion that objective measures of value may measure aspects of alcohol motivation that are not completely captured by to traditional indices of subjective craving.

Stress-induced increases in demand for alcohol on the APT converge with the findings of MacKillop and Ray (2011) who demonstrated increased demand for alcohol following a stress induction. However, there were some notable differences. While both

studies found that stress increased unrestrained consumption (i.e., Intensity) and the maximum acceptable price for a drink (i.e., Breakpoint), the present study found significant increases in maximum expenditure (i.e., O_{max}), whereas MacKillop and Ray did not. Furthermore, Elasticity was significantly decreased by stress in the MacKillop and Ray study but it did not significantly change here. On the whole, the effect sizes for each of the APT indices also tended to be lower in the present study, with the notable exception of O_{max}. This may be attributable to differences in sample characteristics and methodological differences in the APT paradigms and stressors used. First, although the average weekly alcohol consumption was comparable in both studies, the participants in the MacKillop & Ray study were specifically selected based on having an AUDIT score of 8 or greater. Consequently, the participants in their study tended to have higher AUDIT scores on average. This greater alcohol problem severity may have contributed to more robust effects on APT performance. Second, the drink prices assessed on the APTs varied considerably between studies (the maximum drink price was $15 in this study and $1120 in the previous study). Finally, it is possible that personalized stress inductions may have a more robust effect on demand than social-evaluative stressors. In fact, the literature suggests that guided imagery stress inductions are a more consistent trigger of craving across addictive substances in comparison to the TSST (Thomas & Bacon, in press). Nonetheless, the present study indicates that stress-induced increases in alcohol demand are not specific to any one type of stressor, although future studies are needed to replicate and extend these findings.

Consistent with the findings of Rousseau et al. (2012), the relative value of alcohol on the cross-commodity AMCP also increased under stress. Again, the

differences in mood induction procedures between these studies suggests that increased value on a cross-commodity task is influenced by negative emotion in general and not just one type of negative affect induction. Above and beyond replication of previous research, the present study had the unique potential to disentangle which aspects of incentive value were most sensitive to stress. Since the AMCP task combined aspects of demand and DRD (i.e., immediate alcohol versus delayed money), changes in one or both of these related processes could be responsible for the increase in AMCP crossover point following stress. Results of the mediation analysis support the causal role of increased demand, as reflected in significant mediation by O_{max} but not increased preference for immediate rewards (i.e., DRD). Increased crossover points, therefore, appear to be attributed to dynamic increases in the value of alcohol rewards specifically and not simply that they were the immediately-available option.

This study also adds to the literature implicating negative reinforcement-driven drinking motives as moderators of alcohol motivation and stress responses. The tendency to consume alcohol as a means of coping with negative emotions has been linked to daily fluctuations in drinking patterns (Grant, Stewart, & Mohr, 2009; Hussong, Galloway, & Feagans, 2005) along with higher overall alcohol consumption and alcohol-related problems (Carey & Correia, 1997; Galen, Henderson, & Coovert, 2001; Martens et al., 2008; Stewart, Zvolensky, & Eifert, 2001). This study confirms that coping motives are also meaningfully related to acute responses to stressors. Similar to Rousseau et al. (2012), individuals who reported drinking as a means of negative reinforcement were the ones who showed the largest increase in AMCP crossover points following stress. However, this study further clarifies this relationship by showing stress-related increases

in incentive value may be specific to situations in which alcohol is actually available for consumption. Coping motives did not moderate increases on the hypothetical APT but did so for the actual-outcome AMCP. One possible explanation for this discrepancy concerns the hypothetical versus actual nature of these tasks. Hypothetical alcohol rewards on the APT did not have the potential to influence the participants' current affective state. This was not the case for the AMCP, on which participants were making choices that directly influenced whether they would receive an alcoholic beverage that could presumably be used to alleviate the negative effects of stress. This apparent difference between hypothetical and actual outcome measures is particularly intriguing considering that Amlung et al. (2012) found close correspondence between hypothetical and actual APT assessments in a similar sample of heavy drinkers. Together with the present study, it appears that behavioral economic measures of incentive value of alcohol are generally consistent across real and hypothetical scenarios, but may differ when alcohol is used as a means to augment acute emotional states in specific subsets of drinkers.

Somewhat surprisingly and counter to the study's hypotheses, acute stress did not affect impulsive choice on the DDT. In fact, participants tended to exhibit less impulsive behavior following stress, although this change was not statistically significant. While these results are inconsistent with prior studies showing that negative affect increases impulsive and risky behavior (Flora et al., 2003; Gray, 1999; Knapp & Clark, 1991; Lighthall et al., 2009; Porcelli & Delgado, 2009; Starcke et al., 2008; Tice et al., 2001; van den Bos et al., 2009), previous studies that have investigated the effects of stress on DRD specifically have been equivocal (Lempert et al., 2012; White et al., 2008). In fact,

the only study to show increased DRD following stress found that the effect was specific to only those individuals who reported high overall perceived stress level (Lempert et al., 2012). Furthermore, the nature of the stressor used (i.e., whether it was future-oriented or present-oriented) also seems to influence stress effects (Lempert et al., 2012). One key difference between the present study and past ones is that the current participants were heavy drinkers and not normal controls. As such, it is conceivable that for drinkers, acute stress may increase the salience of alcohol rewards specifically since alcohol is a highly sought after reward for these individuals. The salience of immediate money, however, may not be similarly affected. Since this is the first study to investigate acute stress effects on DRD in drinkers, this hypothesis is necessarily conjecture and further research is needed to confirm these initial results.

The second component of this study involved exposing participants to alcohol cues after the stress induction, to determine whether changes in craving and incentive value were further exacerbated by alcohol-related stimuli. The results did not support the study's hypotheses: although the alcohol cue exposure produced significantly higher craving ratings and increased heart rate compared to the neutral cue exposure, none of the behavioral economic indices showed a matching increase. The overall pattern of results indicated that the value of alcohol conformed to an inverted U-shape, with initially moderate levels at baseline, a significant increase for both the AMCP and APT following stress, and then uniformly returning to near baseline levels after the cue exposure for both neutral and alcohol conditions. The only exception was Breakpoint which decreased following neutral cues but did not change after alcohol cues. These results are inconsistent with prior research suggesting that exposure to alcohol cues increases both

subjective craving and demand (Amlung et al., 2012; MacKillop, O'Hagen, et al., 2010). However, one unique aspect of the present study was that all participants were in put in an emotionally-charged, stressed state prior to interacting with the beverage cues. Thus, these results offer initial evidence that the acute effects stress may attenuate subsequent cue effects, at least in the case of incentive value. This is consistent with the findings of Ray (2011), in which stress alone was found to increase alcohol motivation to the same degree as an alcohol cue exposure, but the combined effects of stress and cues were not additive. The absence of a neutral (non-stress) control group in this study prevented a similar analysis of alcohol cue effects independent of a prior stressor. An important priority for future research will be to disentangle the apparent discrepancy between stress and cue effects on subjective craving and objective measures of alcohol motivation.

The present results have important implications for theoretical models linking stress and addiction. This study further supports the notion that stress plays an integral role in motivating drinkers to consume alcohol, as suggested by both stress-coping models (e.g., Shiffman, 1982; Khantzian, 1985; Sher & Levensen, 1982) and vulnerability models (e.g., Sinha, 2001). In the latter case, heightened or abnormal responses to both acute and chronic stressors are viewed as risk factors for developing alcohol problems. The present results coalesce with this model by specifying one potential mechanism by which this may occur, that is, increased salience of alcohol rewards under stress. Importantly, Sinha's model also asserts that additional vulnerability factors are in play, namely personality traits, cognitive functioning, and social factors. A priority moving forward will be to elucidate how these ancillary factors influence stress-induced changes in value. One particularly promising avenue will be to examine

candidate genetic moderators of these effects. For example, genetic variants underlying dopaminergic neurotransmission have been linked to stress and its corresponding effects on impulsivity (White et al., 2009). Similarly, Ray (2011) reported that variation in genes coding for corticotrophin-releasing hormone (CRH) binding proteins and opioid binding receptors was associated with greater affective response to stress and cue-induced craving, respectively.

Finally, from a translational standpoint, these findings have potentially important implications in the context of treatment for AUDs. Stressful events and other forms of negative affect are often cited as contributors to post-treatment lapse and relapse (Sinha, 2001). To this end, the present study suggests that these decisions to drink may be due, in part, to an increase in the desirability of alcoholic beverages under stress. Developing effective skills for managing stress and coping with negative affect is a key component of established treatments for AUDs (e.g., Monti, Kadden, Rohsenow, Cooney, & Abrams, 2002). The present study suggests that such treatments may be improved by adding behavioral economic measures of incentive value as supplementary assessments, particularly since measures of DRD and demand have been shown to predict treatment outcomes in past research (e.g., Krishnan-Sarin et al., 2007; MacKillop & Kahler, 2009; MacKillop & Murphy, 2007; Sheffer et al., 2012; Tucker et al., 2002; Yoon et al., 2007). Behavioral economic paradigms can also be relatively easily adapted to assess alcohol motivation during *in vivo* exposures in clinical settings, albeit in hypothetical forms. Most importantly, however, the present results suggest that these supplements may be especially important for those individuals who use alcohol as a means to directly cope with stress and negative affect. Screening for coping motives and general level of stress

may allow for better prediction of which clients may be at greater risk for turning to alcohol for negative reinforcement and, consequently, may experience more setbacks over the course of their treatment.

These findings should be considered in the context of the study's limitations. First, although the participants in this study were all heavy drinkers, they were predominately young, highly-educated, and Caucasian. Participants were also selected based on their level of alcohol consumption, not necessarily the presence of a clinically-significant AUD. As such, caution is needed when generalizing these findings to the larger population as the present sample may not be representative of all drinkers or addictive behaviors in general. Second, the sample size in this study was adequately powered to detect both the between and within-subjects effects, but this may not have been the case for the moderation analyses that examined upper and lower quartiles of participants. Future studies should replicate these findings in larger samples that are more diverse both in terms of demographics and alcohol problem severity. For example, a logical extension of this study would be to examine stress and cue effects across multiple strata of alcohol misuse, including light drinkers, heavy drinkers without AUDs, and heavy drinkers with AUDs. Determining whether similar effects are present in individuals who abuse other addictive substances (i.e., smokers, illicit drug users) is another important direction. In addition, no biochemical markers of stress response (i.e., salivary cortisol) were collected to further validate the stress induction. Nonetheless, the stress induction had a robust effect on both subjective affect and psychophysiological arousal, and the recent meta-analysis by Dickerson and Kemeny (2004) offers strong support for the propensity for stress inductions like the TSST to elicit robust increases in

stress hormone levels. The design of this study did not include a control group for the stress induction as has been done in previous research. This necessarily precluded examining independent effects of stress and cues; however this design was motivated by the primary goal of investigating combined effects of stress and cues. Furthermore, a fully factorial 2x2 design (i.e. stress/non-stress vs. neutral/alcohol cues) would have required effectively doubling the sample size to counteract the accompanying loss in statistical power. Future large-scale studies would benefit from such a design and may also allow for more direct comparisons to existing studies (e.g., Ray, 2011). One final limitation concerns the temporal spacing of the stress induction and cue exposures. The time interval between manipulations was intentionally kept brief to prevent decay of the acute stressor, but this may have inadvertently contributed to carryover effects on the behavioral economic measures (i.e., participants' responses on prior assessments unduly influencing future ones). Nonetheless, the interval between assessments was comparable to previous studies of stress and cue-elicited craving (e.g., Amlung et al., 2012; MacKillop, O'Hagen et al., 2012; MacKillop & Ray, 2011; Ray, 2011).

Conclusions

In summary, the present study found that both subjective craving and incentive value of alcohol were dynamically influenced by the experience of acute psychosocial stress. Stress effects on incentive value were also found to be the most robust in drinkers who were primarily motivated by negative reinforcement. Preferences for immediate monetary rewards on DRD measures were not similarly affected. Counter to predictions, the combined effects of stress and alcohol cues on incentive value were not additive, despite additive effects on subjective craving. These results add to the literature

characterizing state-based properties of behavioral economic variables and lend further support for a behavioral economic approach to assessing acute changes in drinking motivation. Finally, this study suggests that adding the behavioral economic concept of incentive value to existing laboratory stress models may aid in future development of stress-related psychological and pharmacological interventions for alcoholism and other addictive disorders.

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Table 1
Sample Characteristics

Characteristic	Overall Mean (*SD*) / % / Median [IQR]	Alcohol Cues Mean (*SD*) / % / Median [IQR]	Neutral Cues Mean (*SD*) / % / Median [IQR]
N	84	42	42
Race			
Caucasian	64%	64%	64%
African American	20%	19%	22%
Asian	11%	10%	12%
American Indian / Alaskan Native	1%	2%	0%
Mixed Race	4%	5%	3%
Ethnicity	7% Hispanic	7% Hispanic	7% Hispanic
Age	22.24 (2.24)	22.10 (2.42)	22.38 (2.06)
Income	$65k [$40k–$80k]	$60k [$20k–$80k]	$65k [$40k–$80k]
Education (Years)	15.26 (1.23)	15.14 (0.88)	15.37 (1.50)
Drinks / Week	16.08 (8.95)	16.80 (8.75)	15.38 (9.19)
AUDIT	10.45 (4.65)	10.62 (4.54)	10.29 (4.76)

Note: AUDIT = Alcohol Use Disorders Identification Test; SD = standard deviation; ICR = inter-quartile range. Group difference column reflects comparison between alcohol and neutral cues groups.

Table 2
Acute Stress Induction Manipulation Checks

Variable	Baseline *M (SE)*	Post-Stress *M (SE)*	$F_{(1,83)}$	p	η_p^2
Craving	2.84 (0.23)	3.13 (0.27)	4.15	.045	.05
Stressed	2.65 (0.25)	4.40 (0.29)	45.07	<.001	.35
Nervous	2.40 (0.23)	4.15 (0.28)	54.23	<.001	.40
Relaxed	7.57 (0.17)	4.85 (0.26)	98.75	<.001	.54
Calm	7.80 (0.21)	5.00 (0.25)	100.02	<.001	.55
Happy	6.87 (0.18)	5.46 (0.23)	57.27	<.001	.41
Sad	1.43 (0.18)	2.06 (0.24)	7.99	.006	.09
MAP	81.63 (1.03)	91.54 (1.16)	82.16	<.001	.50
Heart Rate	65.81 (1.01)	68.49 (1.23)	13.64	<.001	.14

Note: MAP = mean arterial pressure; M = mean; SE = standard error of the mean.

Table 3
Cue Exposure Manipulation Check

	Alcohol Cues		Neutral Cues	
Variable	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***
Craving	2.70 (0.30)	3.14 (0.29)	3.57 (0.43)	2.61 (0.35)
Stressed	4.00 (0.40)	2.29 (0.27)	4.81 (0.41)	3.36 (0.38)
Nervous	3.83 (0.43)	2.17 (0.29)	4.48 (0.37)	3.19 (0.34)
Relaxed	4.74 (0.35)	6.67 (0.27)	4.95 (0.39)	6.62 (0.31)
Calm	4.93 (0.32)	6.71 (0.24)	5.07 (0.38)	6.74 (0.31)
Happy	5.24 (0.33)	6.17 (0.26)	5.69 (0.31)	6.12 (0.29)
Sad	2.07 (0.38)	1.64 (0.25)	2.05 (0.31)	2.19 (0.30)
MAP	93.14 (1.44)	88.67 (1.78)	89.94 (1.80)	85.70 (2.01)
Heart Rate	66.95 (1.71)	67.45 (1.62)	70.02 (1.75)	66.74 (1.50)

Note: MAP = mean arterial pressure; ME = Main effect; M = mean; SE = standard error of the mean; T x C = time x condition. interaction.

Table 3 (continued)

	ME Time			***ME Condition***			***T x C***		
Variable	$F_{(1,82)}$	*p*	η_p^2	$F_{(1,82)}$	*p*	η_p^2	$F_{(1,82)}$	*p*	η_p^2
Craving	2.46	.120	.03	0.12	.725	.00	17.97	<.001	.18
Stressed	44.39	<.001	.35	4.13	.045	.05	0.30	.583	.00
Nervous	56.45	<.001	.41	3.09	.082	.04	0.94	.335	.01
Relaxed	53.49	<.001	.39	0.04	.837	.00	0.28	.596	.00
Calm	70.68	<.001	.46	0.04	.835	.00	0.08	.773	.00
Happy	12.34	.001	.13	0.29	.591	.00	1.67	.199	.02
Sad	0.61	.438	.01	0.42	.518	.01	2.43	.123	.03
MAP	16.76	<.001	.17	1.86	.177	.02	0.01	.914	.00
Heart Rate	4.39	.039	.05	0.28	.599	.00	8.11	.006	.09

Table 4

Effects of Acute Stress on of Incentive Value

Variable	Baseline *M (SE)*	Post-Stress *M (SE)*	$F_{(1,83)}$	p	η_p^2
AMCP-CP	5.37 (0.35)	5.92 (0.37)	5.92	.017	.07
Intensity[a]	5.88 (0.47)	6.26 (0.47)	4.61	.035	.05
Breakpoint[a]	6.17 (0.46)	6.66 (0.43)	8.20	.005	.09
Omax[a]	8.54 (0.86)	9.50 (0.83)	9.23	.003	.10
Elasticity[b]	0.05 (0.01)	0.04 (0.01)	1.84	.179	.02
ICR	0.21 (0.01)	0.19 (0.01)	3.15	.080	.04

Note: [a] Variable was square root transformed prior to analysis (untransformed values reported in table); [b] Variable was logarithmically transformed prior to analysis (untransformed values reported in table); AMCP-CP = crossover point on alcohol multiple choice procedure; ICR = impulsive choice ratio on delay discounting task; M = mean; SE = standard error of the mean.

Table 5

Effects of Cue Exposure on Incentive Value

	Alcohol Cues		Neutral Cues	
Variable	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***
AMCP-CP	5.45 (0.40)	5.14 (0.42)	6.39 (0.61)	5.81 (0.53)
Intensity[a]	6.07 (0.67)	5.81 (0.70)	6.45 (0.65)	5.91 (0.62)
Breakpoint[a]	5.77 (0.55)	5.79 (0.53)	7.55 (0.64)	7.05 (0.70)
Omax[a]	8.23 (1.11)	7.88 (1.08)	10.76 (1.21)	9.58 (1.20)
Elasticity[b]	0.05 (0.01)	0.04 (0.01)	0.04 (0.01)	0.04 (0.01)
ICR	0.21 (0.02)	0.21 (0.02)	0.18 (0.02)	0.18 (0.02)

Note: [a] Variable was square root transformed prior to analysis (untransformed values reported in table); [b] Variable was logarithmically transformed prior to analysis (untransformed values reported in table); AMCP-CP = crossover point on alcohol multiple choice procedure; ICR = impulsive choice ratio on delay discounting task; M = mean; SE = standard error of the mean; ME = main effect; T x C = time x condition interaction.

Table 5 (continued)

	ME Time			***ME Condition***			***T x C***		
Variable	$F_{(1,82)}$	p	η_p^2	$F_{(1,82)}$	p	η_p^2	$F_{(1,82)}$	p	η_p^2
AMCP-CP	10.68	.002	.12	1.37	.246	.02	1.04	.311	.01
Intensity[a]	9.33	.003	.10	0.12	.730	.00	0.44	.507	.01
Breakpoint[a]	2.98	.088	.04	2.69	.105	.03	4.42	.039	.05
Omax[a]	9.78	.002	.11	1.93	.168	.02	3.21	.077	.04
Elasticity[b]	1.82	.181	.02	2.74	.102	.03	0.06	.803	.00
ICR	0.04	.839	.00	1.79	.184	.02	0.16	.688	.00

Table 6

Intercorrelations among Behavioral Economic Indices

Baseline	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1. AMCP-CP	—					
2. Intensity[a]	.35**	—				
3. Breakpoint[a]	.44***	.40***	—			
4. Omax[a]	.46***	.53***	.84***	—		
5. Elasticity[b]	-.35**	-.38***	-.78***	-.78***	—	
6. ICR	.32**	.28*	.22*	.20	-.18	—

Post-Stress	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1. AMCP-CP	—					
2. Intensity[a]	.26*	—				
3. Breakpoint[a]	.48***	.42***	—			
4. Omax[a]	.45***	.59***	.90***	—		
5. Elasticity[b]	-.47***	-.53***	-.97***	-.95***	—	
6. ICR	.40***	.21	.19	.22*	-.23*	—

Post-Cues	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1. AMCP-CP	—					
2. Intensity[a]	.23*	—				
3. Breakpoint[a]	.41***	.35**	—			
4. Omax[a]	.48***	.57***	.86***	—		
5. Elasticity[b]	-.48***	-.51***	-.95***	-.93***	—	
6. ICR	.40***	.24*	.19	.21	-.27*	—

Note: [a] Square root transformed; [b] Logarithmic transformed; AMCP-CP = crossover point on alcohol multiple choice procedure; ICR = Impulsive choice ratio on delay discounting task. *p<.05; **p<.01; ***p<.001.

Table 7
Mediation Analysis of Stress Effects on AMCP Crossover Point

Mediator	*B*	SE	*β*	*p*
O_{max}				
Difference	0.75	0.35	0.23	.04
Sum	0.05	0.10	0.06	.58
Intercept	0.39	0.24	—	.10
Breakpoint				
Difference	0.99	0.52	0.21	.06
Sum	0.20	0.15	0.15	.19
Intercept	0.41	0.23	—	.08
Intensity				
Difference	0.39	0.53	0.08	.46
Sum	0.02	0.15	0.02	.88
Intercept	0.51	0.24	—	.03

Note: SE = standard error; Per Judd et al. 2001: Difference = value of mediator at Post-Stress minus value of mediator at Baseline; Sum = value of mediator at Post-Stress plus value of mediator at Baseline (mean-centered); Intercept = residual effect on criterion variable above and beyond mediation.

Table 8

Moderators of Stress Effects on Incentive Value

Coping Motives	**High Coping Motives**		**Low Coping Motives**		***ME Time***			***ME Group***			***Moderation T x G***		
Variable	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	$F_{(1,45)}$	p	η_p^2	$F_{(1,45)}$	p	η_p^2	$F_{(1,45)}$	p	η_p^2
AMCP-CP	5.54 (0.72)	6.67 (0.79)	5.12 (0.72)	5.00 (0.71)	3.24	.079	.07	1.11	.298	.02	4.99	.031	.10
Intensity[a]	6.04 (0.83)	6.96 (0.88)	5.55 (0.99)	5.71 (0.95)	4.37	.042	.09	1.31	.259	.03	0.36	.553	.01
Breakpoint[a]	7.17 (0.87)	8.26 (0.87)	5.30 (0.98)	5.98 (0.88)	10.11	.003	.18	4.55	.038	.09	0.07	.789	.00
Omax[a]	10.65 (2.01)	11.43 (1.61)	7.65 (1.70)	8.82 (1.73)	5.63	.022	.11	2.63	.112	.06	0.06	.802	.00
Elasticity[b]	0.03 (0.00)	0.02 (0.00)	0.07 (0.02)	0.06 (0.02)	1.11	.297	.02	2.33	.134	.05	0.96	.332	.02
ICR	0.23 (0.02)	0.23 (0.03)	0.20 (0.23)	0.17 (0.02)	1.50	.226	.03	1.64	.206	.04	0.70	.408	.02
Alcohol Use & Misuse	**High AUDIT**		**Low AUDIT**		***ME Time***			***ME Group***			***Moderation T x G***		
Variable	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	$F_{(1,44)}$	p	η_p^2	$F_{(1,44)}$	p	η_p^2	$F_{(1,44)}$	p	η_p^2
AMCP-CP	5.63 (0.64)	6.43 (0.68)	4.14 (0.64)	5.11 (0.69)	7.85	.008	.15	2.56	.117	.06	0.07	.790	.00
Intensity[a]	6.48 (0.76)	6.65 (0.73)	4.48 (0.84)	4.96 (0.92)	1.86	.180	.04	4.21	.046	.09	0.26	.614	.00
Breakpoint[a]	6.17 (0.91)	6.52 (0.74)	4.81 (0.59)	5.20 (0.63)	2.90	.096	.06	1.81	.186	.04	0.04	.840	.00
Omax[a]	8.04 (1.51)	9.26 (1.39)	6.37 (1.24)	7.33 (1.39)	7.97	.007	.15	1.16	.286	.03	0.58	.451	.01
Elasticity[b]	0.05 (0.02)	0.03 (0.01)	0.07 (0.02)	0.07 (0.02)	3.38	.073	.07	2.59	.115	.06	0.45	.505	.01
ICR	0.26 (0.03)	0.27 (0.02)	0.16 (0.03)	0.15 (0.03)	0.04	.839	.00	9.53	.003	.18	1.52	.224	.03
Gender	**Males**		**Females**		***ME Time***			***ME Group***			***Moderation T x G***		
Variable	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	**Baseline** ***M (SE)***	**Post-Stress** ***M (SE)***	$F_{(1,82)}$	p	η_p^2	$F_{(1,82)}$	p	η_p^2	$F_{(1,82)}$	p	η_p^2
AMCP-CP	5.54 (0.49)	6.09 (0.52)	5.21 (0.49)	5.75 (0.53)	5.85	.018	.07	0.24	.624	.00	0.00	.982	.00
Intensity[a]	6.90 (0.73)	7.23 (0.73)	4.86 (0.56)	5.29 (0.55)	4.56	.036	.05	4.56	.036	.05	0.11	.741	.00
Breakpoint[a]	5.88 (0.61)	6.31 (0.57)	6.47 (0.69)	7.01 (0.65)	8.10	.006	.09	0.50	.481	.01	0.01	.923	.00
Omax[a]	8.58 (1.26)	9.86 (1.29)	8.49 (1.18)	9.13 (1.05)	9.17	.003	.10	0.01	.933	.00	0.44	.509	.01
Elasticity[b]	0.05 (0.01)	0.04 (0.01)	0.05 (0.01)	0.05 (0.01)	1.82	.181	.02	0.05	.830	.00	0.20	.655	.00
ICR	0.25 (0.02)	0.23 (0.02)	0.18 (0.02)	0.16 (0.02)	3.10	.082	.04	7.98	.006	.09	0.02	.883	.00

Note: [a] Square root transform prior to analysis (untransformed values reported in table); [b] Logarithmic transform prior to analysis (untransformed values reported in table); AMCP-CP = crossover point on alcohol multiple choice procedure; AUDIT = Alcohol Use Disorders Identification Test; ICR = impulsive choice ratio on delay discounting task; M = mean; SE = standard error of the mean; ME = main effect; T x G = time x group interaction.

Table 9

Moderators of Cue Effects on Incentive Value

Alcohol Use & Misuse		**High AUDIT**		**Low AUDIT**		***Moderation T x G x C***		
Variable	**Condition**	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***	**Post-Stress** ***M (SE)***	**Post-Cues** ***M (SE)***	$F_{(1,42)}$	p	η_p^2
Intensity[a]	Alcohol	5.73 (0.74)	5.47 (0.73)	4.30 (0.63)	4.80 (0.93)	3.70	.070	.08
	Neutral	8.38 (1.44)	8.25 (1.46)	5.46 (1.56)	4.62 (1.39)			
ICR	Alcohol	0.30 (0.03)	0.29 (0.03)	0.13 (0.04)	0.17 (0.04)	3.45	.061	.08
	Neutral	0.22 (0.03)	0.23 (0.03)	0.16 (0.04)	0.14 (0.03)			

Note: [a] Square root transform prior to analysis (untransformed values reported in table); AUDIT = Alcohol Use Disorders Identification Test; ICR = impulsive choice ratio on delay discounting task; M = mean; SE = standard error of the mean; T x G x C = time x group x condition interaction

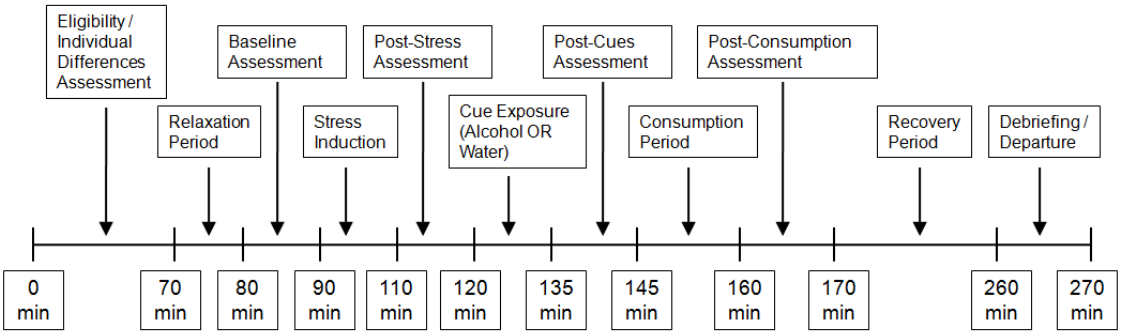

Figure 1

Schematic Diagram of Laboratory Session Components

Assessments are listed in top row, exposures and other key events are listed in middle row, and corresponding time points relative to the start of the session are provided in the bottom row. Random selection and provision of AMCP outcome (alcohol or money) occurred following Post-Cues assessment.

Figure 2
Representative Images of Laboratory Facilities

Panel A depicts the typical setup for the laboratory stress induction from the participant's perspective, including three confederates seated behind a large conference table and a video camcorder on a tripod aimed at the participant. The bottom two panels depict the simulated bar laboratory (B) and neutral cue environment (C) that were used for the alcohol and neutral cue exposures, respectively.

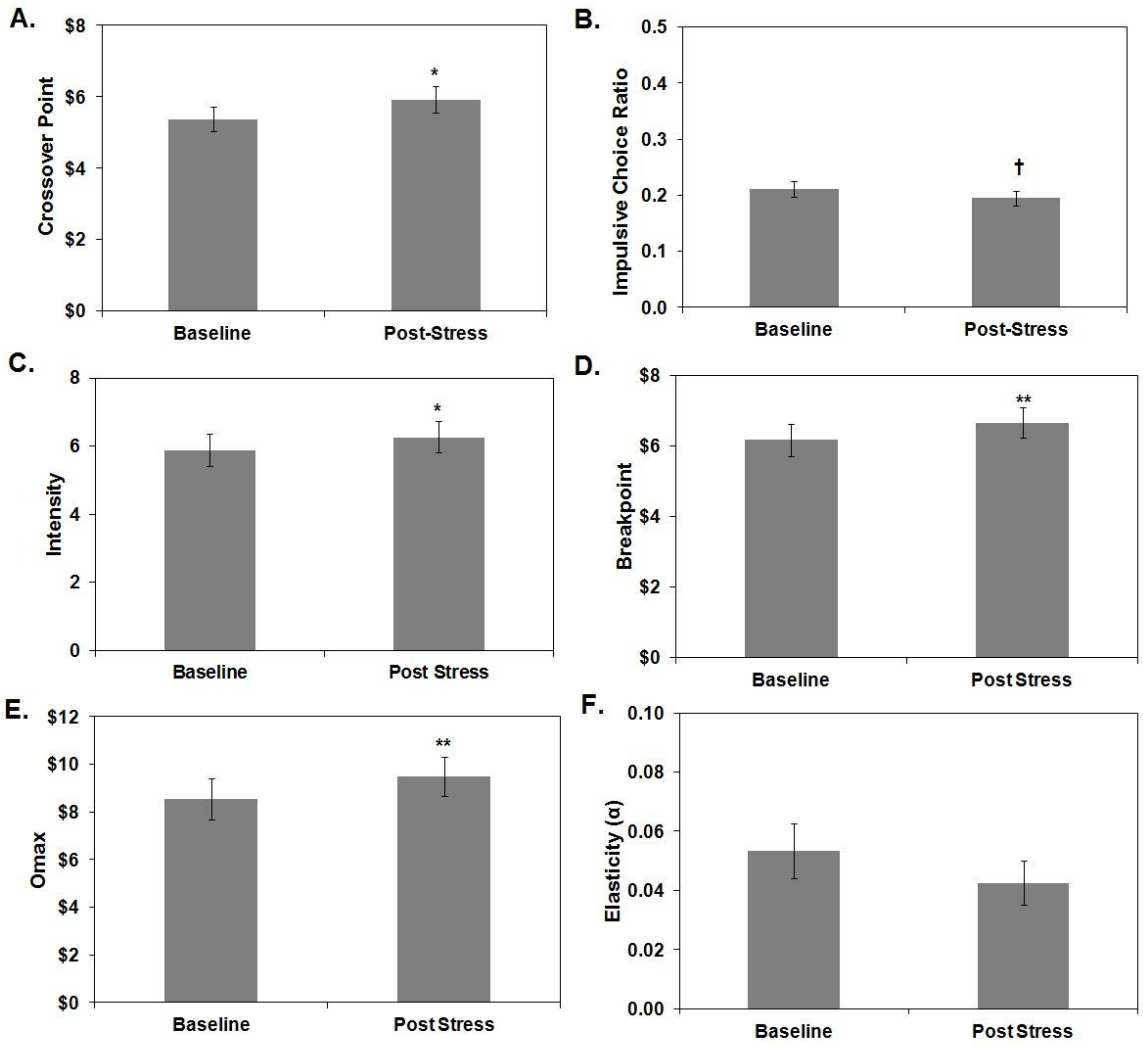

Figure 3
Effects of Acute Stress on Incentive Value

Panel A depicts crossover point on the alcohol multiple choice procedure; Panel B depicts impulsive choice ratio on the delay discounting task; Panels C-F depict the following demand indices on the alcohol purchase task: Intensity (Panel C), Breakpoint (Panel D), O_{max} (Panel E), and Elasticity (Panel F). All values reflect mean (+/- standard error). †p<.10; *p<.05; **p<.01.

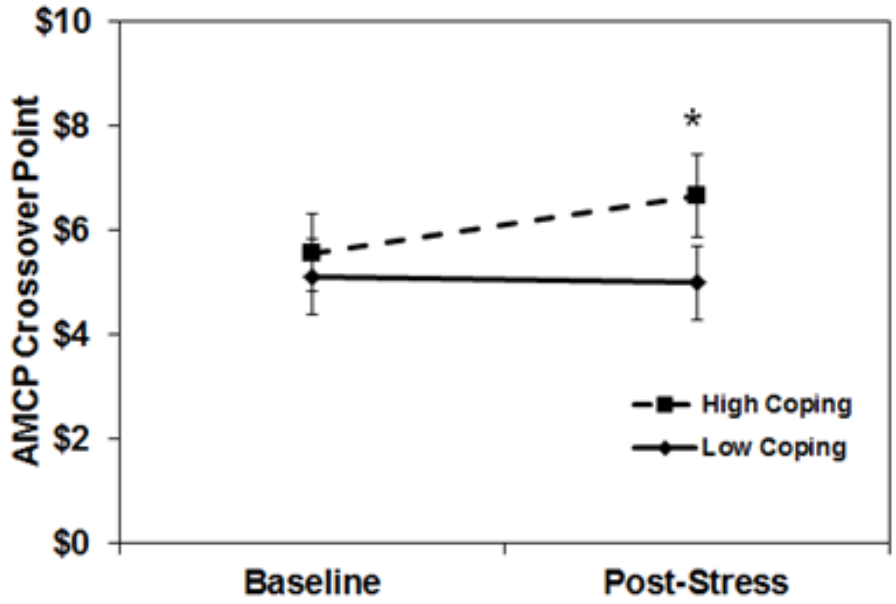

Figure 4
Coping Motives Moderate Stress-Induced Increases in Incentive Value

Stress-induced changes in AMCP crossover point for upper (dashed line, n = 23) and lower (solid line, n = 24) quartiles on the coping subscale of the drinking motives questionnaire. Values reflect mean (+/- standard error). *p < .05.