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Stress and alcohol use: An experimental investigation of cognitive mechanisms

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Abstract

Research suggests that exposure to stressors is associated with greater alcohol consumption, more alcohol-related problems, and a greater likelihood of Alcohol Use Disorder. Theory suggests that cognitive processes, particularly unconscious cognitive processes, are key in determining a coping strategy but both alcohol and chronic exposure to stressors may interfere with these processes. The current study tested one such process, attention bias to alcohol cues, as a mediator in the stressor-alcohol relationship. Thirty-nine participants who endorsed hazardous alcohol consumption patterns were recruited from the community; eligible participants were randomly assigned to a stress-exposure or non-stressful control condition. Participants completed assessments of stress response and alcohol craving before and after exposure to the stressor, and an assessment of alcohol attention bias following stress exposure. Outcome measures were change in alcohol craving and ad libitum alcohol consumption. Analyses included ANCOVAs to test for group differences in outcomes by condition, and serial mediation models to test the stress response and alcohol attention bias as serial mediators using path analysis in Mplus with the model indirect command. Results revealed no significant differences in alcohol outcomes by condition and no significant serial mediation effect of the stress response and alcohol attention bias on the stressor-alcohol relationship. The direction of the coefficients were largely in the anticipated direction, which may suggest a lack of power to detect significant effects due to small sample size. Alternative explanations for null findings include reliability of the measurement of attention bias and sample characteristics, which highlight important considerations for future research.

Stress and alcohol use: An experimental investigation of cognitive mechanisms

by

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1. Introduction

1.1 Public health impact of alcohol and stressors

Recent data from the Center for Disease Control and Prevention's (CDC) Alcohol-Related Disease Impact (ARDI) study demonstrated that excessive alcohol consumption contributed to an average of 87,798 deaths and 2.5 million years of life lost each year from 2006-2010 (Stahre et al., 2014). With 1 in every 10 deaths attributed to excessive alcohol consumption, it remains a leading contributing factor to early mortality in the United States (Stahre et al., 2014). Heavy alcohol consumption has consistently been associated with greater incidences of physical diseases (e.g., cardiovascular disease; Rehm et al., 2010; hypertension; Taylor et al., 2009) and psychiatric disorders (e.g., depression; Rehm et al., 2010). Despite the considerable risks associated with alcohol consumption, rates of alcohol use, high-risk alcohol consumption, and the prevalence of Alcohol Use Disorder (AUD) continue to increase (Grant et al., 2017). Analysis of a nationally representative longitudinal study, the National Epidemiologic Survey on Alcohol and Related Conditions III (NESDARC) revealed that in 2013, 72.7% of American adults reported using alcohol, 12.6% endorsed hazardous levels of alcohol use, and 12.7% met diagnostic criteria, as designated in the *Diagnostic and Statistical Manual of Mental Disorders – 4th edition* (*DSM-IV*; American Psychiatric Association, 2000) for AUD, all of which represent statistically significant increases compared to 2003 prevalence rates (Grant et al., 2017). Hazardous alcohol consumption is a public health concern that does not discriminate; increases in alcohol consumption, hazardous alcohol consumption, and AUD were observed in the majority of demographic groups included in the analysis (Grant et al., 2017). As Americans are using alcohol at increasingly hazardous rates despite the potential for severe consequences, research into the etiology of AUD is crucial to better identify those at risk and inform interventions.

Another public health concern that is nearly ubiquitous in its presence among Americans is stress. Stress is typically defined in terms of a stimulus (i.e., stressor) and a stress response comprised of neuroendocrine, physiological, affective, and cognitive components (Lazarus, 1966). Importantly, stress is a multifaceted process that can differ by type of stressor and individual differences in cognitive and affective processes involved in the appraisal of the stressor and available coping resources (Sinha, 2001). The stress response is an immensely complex process of interactions among biological and psychological processes, and yet exposure to stressors and the stress response have consistently been associated with negative health and psychosocial outcomes. Stressors have been identified as a risk factor serious medical and psychiatric conditions, including cardiovascular disease (Steptoe & Kivimäki, 2013), Alzheimer's disease (Sindi et al., 2017), and depression (Hammen, 2005). Additionally, stressors place a great financial burden on society, with approximately $187 billion in direct healthcare costs and $5.4 billion in indirect costs (e.g., absences from work) attributable to stressors (Hassard et al., 2018). The costs incurred as a result of exposure to and coping with stressors constitute a major public health concern due to their severity and prevalence.

1.2 The stressor-alcohol relationship: research findings

Considerable research effort has been dedicated to investigating the stressor-alcohol relationship using a variety of research designs and methodologies. Correlational studies have demonstrated positive associations between exposure to various types of life stressors and alcohol consumption and/or prevalence of AUD (for a review, see Keyes et al., 2012). Additionally, studies using ecological momentary assessment have demonstrated associations between self-reported stress (Maisto et al., 2017) and discrimination experiences (Livingston et al., 2017) and increased alcohol and other substance use.

In order to attempt to clarify a potential causal relationship between exposure to stressors and alcohol consumption, experimental studies have typically used various laboratory stressors such as the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), Musical Mood Induction Procedure (MMIP; Västfjäll, 2001), and guided imagery (e.g., Sinha et al., 2009) to induce a stress response and measured voluntary alcohol consumption and/or proxies of alcohol consumption (e.g., craving for alcohol). Many studies have reported positive effects of stressors on alcohol or placebo consumption (Cyders et al., 2016; de Wit et al., 2003; Higgins & Marlatt, 1975; Hull & Young, 1983; Kidorf & Lang, 1999; Magrys & Olmstead, 2015; McGrath et al., 2016; Merrill & Thomas, 2013; Miller et al., 1974; Noel & Lisman, 1980; Randall & Cox, 2001; Sinha et al., 2009), alcohol craving (Amlung & MacKillop, 2014; Fox et al., 2007; Hartwell & Ray, 2013), and desire for alcohol (Cooney et al., 1997) as well as elevated autonomic nervous system responses in heavy drinkers (Boschloo et al., 2011; Sinha et al., 2009). On the other hand, several studies have reported no effect of stressors on alcohol or placebo consumption (Larsen et al., 2013; McNair, 1996; Randall & Cox, 2001), craving (Mason et al., 2008), or desire for alcohol (Childs et al., 2011), and some have reported effects in the opposite of expected direction (Bernstein & Wood, 2017; Nesic & Duka, 2006). Methodological differences may account for null or negative effects, such as the use of anticipatory instead of or in addition to experienced stress (Bernstein & Wood, 2017; McNair, 1996), the inclusion of confederates in the drinking context to mimic a more naturalistic setting (Larsen et al., 2013), presentation of beverage cues in addition to positive and negative affective stimuli (Mason et al., 2008), and potential confounding factors (e.g., baseline level of craving, Nesic & Duka, 2006). In addition, one study identified significant differences in ratings of desire to consume alcohol dependent on individual differences in subjective response to alcohol (i.e., experience of sedative versus stimulant effects) despite finding no significant effect of a stressor on alcohol wanting overall (Childs et al., 2011). Despite several studies reporting null or significant effects in the opposite of the expected direction, the majority of research on the effects of stressors on alcohol consumption from multiple fields, using multiple research designs has linked exposure to stressors with greater alcohol consumption and problems. Those studies that have not reported positive effects of stressors on alcohol have cited methodological confounds that may account for null or negative effects. In addition, a recent meta-analysis of laboratory studies of the effect of stressors on alcohol consumption found small to medium effects of stressors on alcohol consumption and alcohol craving such that exposure to a stressor was associated with greater alcohol consumption and craving (Bresin et al., 2018). Therefore, the majority of available research demonstrates that stressor-motivated alcohol consumption warrants significant concern and further attention from researchers regarding the mechanisms by which this problematic pattern of alcohol use develops and is maintained.

1.3 The role of cognitive processing in the stressor-alcohol relationship

Cognitive mechanisms are particularly important to understanding the stressor-alcohol relationship. As outlined in the stress and coping theory, the cognitive component of the stress response represents a crucial process wherein an individual appraises the demand of the stressor and the available coping resources (Lazarus & Folkman, 1984). Cognitive appraisal of the stressor is key, and perhaps even more important in determining coping than the stressor itself (Lazarus & Folkman, 1984). Research has demonstrated that cognitive coping styles (i.e., those emphasizing planning and problem solving) are associated with resilience to stressor (e.g., fewer symptoms of depression; Southwick et al., 2005) and less alcohol consumption (Veenstra et al., 2007). However, individuals experiencing a stress response and/or using alcohol may not be able to engage in the cognitive processing necessary for adaptive coping. Specifically, research has demonstrated that both exposure to a stressor and acute alcohol consumption activate the HPA axis, which results in increases in the primary stress hormone cortisol (Magrys et al., 2013; Rivier & Lee, 1996). Acutely, cortisol facilitates cognitive, physiological, and behavioral responses to stressors (de Kloet et al., 1999), and terminates further activation of the HPA axis via a negative feedback loop (Alim et al., 2012). However, chronic or long-term activation of the HPA axis, as in chronic, heavy alcohol use, has been associated with a neuroendocrine tolerance effect (Blaine & Sinha, 2017). The effect is characterized by a blunted cortisol response in heavy drinkers compared to social drinkers (Mick et al., 2013; Thayer et al., 2006), which may not allow the HPA axis to both activate and terminate efficiently (Alim et al., 2012). In such contexts, different cognitive processes may be more influential in determining coping responses.

1.4 Implicit cognitive processes and hazardous alcohol use

The dual-process model of addiction suggests that substance use behavior is determined via two pathways: one involving explicit cognitive processes and one involving implicit cognitive processes (Stacy & Wiers, 2010). Explicit cognitive processes are conscious, flexible, and easy to learn, but slow to execute and require substantial resources to implement (Redish et al., 2008). Implicit cognitive processes are unconscious, rigid, and difficult to learn, but require little time, effort or resources to implement once established (Redish et al., 2008). Both the stress response (i.e., release of cortisol; Belanoff et al., 2001; Joëls et al., 2006) and acute alcohol intoxication (Fillmore et al., 2006; Thush et al., 2008) have been shown to impair functioning in the prefrontal cortex, a region typically associated with explicit cognitive processes such as planning (Nitschke et al., 2017) and response inhibition (Rae et al., 2015). When explicit cognitive processing is compromised, implicit processes emerge as better predictors of alcohol consumption (Ostafin et al., 2008). As alcohol use progresses from recreational or social use to problematic use, it is driven by negative reinforcement (Koob & Le Moal, 2001) and becomes an unconscious, habit-like response to alcohol stimuli (Heinz et al., 2009). Several theories have cited implicit cognitive processes as the mechanism by which problematic alcohol use develops. Baker and colleagues' (2004) negative reinforcement model of addiction suggests that repeated instances of drinking to ameliorate aversive physical or psychological states change unconscious information-processing systems in ways that foster continued substance use. Similarly, Garland's (2011) cognitive-affective risk model proposes that alcohol use schema are learned through repeated instances of drinking to cope, and then activated unconsciously in response to stressors. Additionally, Garland (2011) cites attention bias, defined as an implicit process that represents the tendency to preferentially attend to one stimulus over another, as a key feature of alcohol use schemas that drive alcohol consumption.

Multiple theories of attention bias specifically have suggested that heavy or chronic substance users preferentially and unconsciously attend to substance use cues in their environment, whereas light or social alcohol users do not (for a review, see Field & Cox, 2008). For example, social alcohol users may drive past an alcohol stimulus (e.g., bar, liquor store) without noticing and heavy alcohol users driving the same route may find themselves attending to the alcohol stimulus without consciously deciding to do so. In empirical studies, attention biases, operationalized as either slower or faster (dependent on the task used) reaction times to alcohol cues compared to control cues have been observed among heavy drinkers or those characterized as alcohol-dependent, but not among light or social drinkers (for reviews, see

Robbins & Ehrman, 2004; Cox, Fadardi, & Pothos, 2006). In studies of alcohol attention bias among clinical populations, greater alcohol attention bias has been associated with greater alcohol consumption and greater risk of relapse, and smaller alcohol attention biases have been associated with better clinical outcomes (i.e., greater reductions in alcohol use; for a review, see Field & Cox, 2008). Additionally, research has demonstrated that exposure to a laboratory stressor results in greater attention biases to alcohol cues, particularly among those who endorse drinking to cope (Ceballos et al., 2012; Field & Powell, 2007; Field & Quigley, 2009).

Despite support for direct relationships between stressors and alcohol consumption, stressors and attention bias, and attention bias and alcohol consumption, only three studies (Field & Powell, 2007; Field & Quigley, 2009; Garland et al., 2012) have attempted to integrate all variables in studies of stressor-induced alcohol consumption. Field and colleagues (Field & Powell, 2007; Field & Quigley, 2009) reported positive effects of a laboratory stressor on alcohol craving and attention bias among coping motivated drinkers. Although the third study (Garland et al., 2012) included measures of stress response, alcohol attention bias, and alcohol craving, the aims and hypotheses of the study were to test alcohol attention bias as a predictor of reactivity to a stressor and alcohol cues, rather than as a mediator of the stressor-alcohol relationship. Thus, the effect of the stressor on alcohol attention bias could not be reported as exposure to the stressor occurred after assessment of alcohol attention bias. Researchers have not yet integrated these findings in a test of a theoretically-supported mechanism, nor have they measured alcohol consumption as an outcome. The integration of results, as well as inclusion of more externally valid alcohol outcome measures are crucial next steps to comprehensively test negative reinforcement theories of alcohol use and inform clinical interventions.

1.5 Clinical applications of implicit cognition

The majority of evidence-based treatments for substance use include stress management and coping strategies (Thomas et al., 2012) which are typically implemented via exercises (e.g., cognitive restructuring, mindfulness) involving explicit cognitive processing. However, individuals using alcohol and/or experiencing a stress response may be less able to utilize the skills learned in therapy due to the pharmacological properties of alcohol and the neurophysiology of the stress response. As an alternative, researchers have recently begun to investigate attention bias modification as a potential adjunct therapy for the treatment of AUD. Attention bias modification interventions have been successful in reversing attention biases (Field et al., 2007; Luehring-Jones et al., 2017; Schoenmakers et al., 2007) and reducing craving (Luehring-Jones et al., 2017) after a single session**.** Interventions using multiple sessions have not only replicated reversals of attention biases, but effects have also generalized to reductions in alcohol use and better clinical outcomes (Fadardi & Cox, 2009; Schoenmakers et al., 2010). Early research on the clinical utility of attention bias modification holds promise, although more research is necessary to maximize the efficacy of these interventions. This may be accomplished in part by identifying patterns and contexts of alcohol use for which attention bias modification may be warranted. The aims of the proposed project are designed to further understanding of one such context, stressor-motivated alcohol consumption, by providing experimental evidence for attention bias as a causal mechanism in this context.

1.6 Coping motivation as a risk factor

Those individuals who endorse a tendency to use alcohol to cope may be at especially high risk for consequences of stressor-motivated alcohol consumption. Most prominent theories of problematic substance use cite negative emotional experiences (i.e., those that characterize a stress response) and attempts to alleviate negative emotional experiences by using alcohol (i.e., negative reinforcement) as the process by which problematic alcohol use develops (e.g., tension reduction theory; Cappell & Herman, 1972; Conger, 1956; self-medication hypothesis; Khantzian, 1985; stress response-dampening model; Sher & Levenson, 1982). Research on coping-motivated (CM) alcohol use, using alcohol to alleviate negative emotional experiences (Cooper, 1994), has consistently substantiated the claims of negative reinforcement models of addiction. Cross-sectional studies have demonstrated positive associations between CM drinking and alcohol consumption and problems (Cooper, 1994; Kuntsche et al., 2008). Longitudinal studies have shown positive associations between CM drinking and alcohol consumption and problems (Holahan et al., 2001), anxiety and depressive symptoms (Holahan et al., 2001), and the development of AUD (Beseler et al., 2008) after ten years. Finally, neuroendocrine research has demonstrated that CM drinking is associated with dysregulation of the primary stress-response system, the hypothalamic-pituitary-adrenal (HPA) axis (Wemm et al., 2013). The majority of the experimental research on the stressor-alcohol relationship has been conducted among broader populations, rather than exclusively those who endorse CM drinking, and suggests that exposure to stressors can be associated with hazardous drinking regardless of CM drinking. However, a smaller body of research suggests that the tendency to endorse CM drinking may have additional utility in identifying individuals who may be at particularly high risk for alcohol consumption and associated consequences associated with exposure to stressors.

1.7 Specific aims and hypotheses

This study was designed to fill an important gap in the literature by conducting an experimental investigation of the effects of exposure to a stressor on alcohol consumption via attention bias to alcohol cues. The study had two specific aims and one exploratory aim, as follows.

Aim 1. To replicate findings of increased alcohol consumption and craving following exposure to a stressor in a laboratory setting. We hypothesized that exposure to a stressor increases voluntary alcohol consumption and self-reported craving compared to exposure to a non-stressful control.

Aim 2. To test the stress response and attention bias to alcohol cues as mediators in the relationship between the stressor and alcohol consumption/craving. We hypothesized that the stress response and attention bias to alcohol cues mediate the relationship between the stressor and alcohol consumption/craving, such that greater response to the stressor is associated with greater attention biases to alcohol cues, and greater attention bias is associated with greater voluntary alcohol consumption/craving.

Exploratory aim. To test an exploratory moderated mediation model in which coping motivation moderates the effect of the stressor on alcohol consumption/craving via the stress response and attention bias. We hypothesized that coping motivation moderates the effect of the stressor on alcohol consumption/craving via the stress response and attention bias such that the effect is stronger among those who endorse more frequent coping motivation for alcohol use.

2. Method

2.1 Participants

Participants were 39 individuals recruited from the Syracuse community via flyers and online advertising. Flyers were posted around the Syracuse University campus, SUNY College of Environmental Science and Forestry campus, and a variety of restaurants and bars in the downtown Syracuse area. Online advertisements were posted on several social media websites (e.g., Facebook, Twitter). Flyers and online advertisements included the language referencing the purpose of the study as related to "cognitive performance of alcohol users" and that participation would involve "answering questions about your health behaviors, completing measures of cognitive performance, and rating alcoholic beverages." Therefore, participants were not aware of the true purpose of the study (i.e., as related to stress and alcohol consumption) if and when they telephoned the study recruitment phone number. Inclusion criteria were being 21-65 years of age, English-speaking, liking beer, and being a hazardous drinker as indicated by scoring above specified cutoffs (≥3 for women, ≥4 for men) on the Alcohol Use Disorders Identification Test-Consumption (AUDIT-C; Bush et al., 1998). Theory suggests that stressor-motivated alcohol use develops as a result of learned associations (e.g., Baker et al., 2004; Garland et al., 2011) and requires both time and experience with alcohol consumption in response to stressors to develop. Although two studies have demonstrated effects of stressors on attention bias to alcohol cues and alcohol craving (Field & Powell, 2007; Field & Quigley, 2009) among light/social drinkers, several others have reported null (Samoluk & Stewart, 1996; Söderpalm Gordh et al., 2011; Thomas et al., 2014; Wardell et al., 2012) or negative (Bernstein & Wood, 2017) effects on alcohol consumption and/or craving among light/social drinkers. Therefore, alcohol users endorsing hazardous levels of alcohol consumption were the target population for this study. Participants were excluded if they endorsed any medical or psychiatric conditions or reported use of any medications contraindicated with alcohol consumption.

2.2 Research design.

The study was a 2 (stressor/no stressor) group, between-subjects, randomized design.

2.3 Measures.

Alcohol use status.

Alcohol use status was assessed using the Alcohol Use Disorders Identification Test - Consumption-C (AUDIT-C, Bush et al., 1998) to determine initial eligibility. The AUDIT-C is a three-item questionnaire derived from the original ten-item Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) that assesses an individual's risk for alcohol-related problems. The AUDIT-C includes only the items from the AUDIT that assess alcohol consumption, (typical frequency, typical quantity, and frequency of binge drinking). Each item is scored on a 0-4 scale. Research supports the reliability and validity of the AUDIT-C, and studies in the United States suggest a revision to the binge drinking question (i.e., binge drinking defined as 5 versus 6 standard drinks) to account for differences in the size of standard drinks in different countries (Dawson et al., 2005; Hagman, 2015; Reinert & Allen, 2007). Research has suggested different cutoff scores for men (≥4) and women (≥3) as optimal for detecting hazardous alcohol use patterns (Reinert & Allen, 2007). Internal consistency in the current sample was acceptable ($\alpha = .66$). Participants initially completed the AUDIT-C during a phone screen, and the AUDIT-C was re-administered in person to verify eligibility prior to beginning any experimental procedures. If there was a discrepancy between a participant’s phone screen and in-person AUDIT-C score, the in-person AUDIT-C was used to determine eligibility as it better reflected recent drinking patterns. Social desirability has been shown to affect reporting of stigmatized behaviors such as alcohol consumption and risky drinking (Davis et al., 2010) and may have a greater effect on in-person reporting versus reporting via phone. In order to minimize the effect of social desirability, the AUDIT-C was administered electronically. Electronic administration of the AUDIT-C has been associated with a greater likelihood of detecting at-risk drinking compared to oral and paper administrations of the AUDIT-C (Graham et al., 2007).

Coping motivation.

The Drinking Motives Questionnaire-Revised (DMQ-R, Cooper, 1994) is a self-report measure containing 20 items assessing how often a participant drinks for each of four motivational factors: coping, enhancement, conformity, and social (Cooper, 1994). Participants reported drinking frequency for each reason over the past 90 days on a 6-point scale (1 = "never/almost never", 6 = "almost always/always"). The DMQ-R demonstrated good construct and predictive validity by discriminating different antecedents and drinking patterns by motive, which are consistent across age, gender and race (Cooper, 1994). Internal consistency in the current sample was excellent (α=.90).

Stress response.

The Positive and Negative Affect Scale (PANAS; Watson et al., 1988) and measures of heart rate and blood pressure were used to measure stress response. The PANAS consists of 20 items, 10 measuring negative affect and 10 measuring positive affect. Participants were instructed to rate their current affect on a 5-point Likert scale from 1 ("very slightly or not at all") to 5 ("extremely"). Alternative measures of negative affect were considered but the PANAS was selected as a well-validated brief measure of negative affect. Specifically, measures based on the Affect Circumplex model (Yik et al., 2011) were considered due to their ability to provide fine-grained measurements of affect based on two dimensions (arousal and valence). However, the research design was intended to induce a specific combination of activated unpleasant affect only, and similar research designs have demonstrated the ability of laboratory stressors to induce the specific combination of arousal and negative valence as assessed by measures of the Affect Circumplex (Heponiemi et al., 2005). Therefore, it was determined that using a measure that assessed only the intended activated unpleasant affect, rather than a measure that assessed all possible combinations of arousal/valence (i.e., deactivated/unpleasant, activated/pleasant, deactivated/pleasant) was preferable. The PANAS was developed based on Watson and colleagues' (1999) Negative Activation theory of affect, shares substantial item overlap with items assessing the activated unpleasant quadrant of circumplex measures, and has been used extensively in stress-induction paradigms to assess the affective component of the stress response (Thomas et al., 2012). Therefore, it was chosen for use in this study as the measure of the affective component of the stress response as it was believed to be the most effective in assessing the intended construct. Internal consistency in the current sample ranged from good to excellent at all timepoints (α's = .83 - .90) Systolic and diastolic blood pressure were used to calculate mean arterial pressure (MAP), a commonly used indicator of the physiological component of the stress response that is well-suited to stress-induction designs (Thomas et al., 2012). Change scores (1st post-manipulation assessment-baseline assessment) were computed for heart rate, MAP, and the negative affect subscale of the PANAS and were used as indicators of the stress response.

Attention bias.

The visual probe task (Miller & Fillmore, 2010) was used to measure attention bias to alcohol cues. To complete this task, participants were required to respond to a probe presented on a computer screen by pressing a corresponding key on the keyboard (i.e., "e" key if the probe appears on the left, "i" key if the probe appears on the right). Participants were first presented with two pictures side-by-side on the computer screen. After a short period of time (i.e., less than 1 second), the pictures disappeared and the probe replaced one of the two pictures. Picture stimuli included alcohol, and color- and shape-matched control stimuli (e.g., soda), and neutral simuli (e.g., stapler). Alcohol trials consisted of one alcohol stimulus and one neutral stimulus, and control trials consisted of one control stimulus and one neutral stimulus. Participants completed 10 practice trials consisting of all neutral stimuli, during which they received feedback for incorrect responses, followed by 80 test trials consisting of 40 alcohol + neutral stimulus pairings and 40 control + neutral stimulus pairings. The number of trials is consistent with similar studies assessing alcohol attention bias; significant attention biases to alcohol cues have been demonstrated using visual probe task administrations with fewer (e.g., Field & Powell, 2007) and more (e.g., Miller & Fillmore, 2009) trials. The number of trials used in this study was chosen to balance the need for enough trials for sufficient reliability with the need to complete the assessments of attention bias and alcohol craving and consumption within the time constraint imposed by the duration of the stress response. As suggested by Field and Quigley (2009), duration of stimulus presentation was 500 milliseconds to reflect maintenance of attention rather than initial orienting. The dependent variable was reaction time; participants were thought to respond more quickly if the probe replaced the picture to which they were more attentive. Thus, a heavy alcohol user should respond more quickly when the probe replaced the alcohol stimulus compared to when the probe replaced the neutral stimulus. The dependent variable was calculated by subtracting reaction times on congruent alcohol trials (e.g., when the probe replaced the alcohol stimulus) from reaction times on incongruent alcohol trials (e.g., when the probe replaced the neutral stimulus); a positive score indicates a faster response to alcohol cues and therefore an attention bias to alcohol cues. Trials with incorrect responses and reaction time latencies of less than 200 milliseconds were considered outliers and were excluded from calculation of attention bias per previously established guidelines (Miller & Fillmore, 2010).

Craving for alcohol.

Craving for alcohol was assessed using the Alcohol Urge Questionnaire (AUQ; Bohn et al., 1995). The AUQ consists of 8 items rated on a 7-point Likert scale. Responses indicate the extent to which participants agree/disagree with statements related to desire to drink, expectancies of alcohol consumption, and ability to avoid alcohol consumption if it were available. The AUQ has demonstrated strong internal consistency and convergent/discriminant validity (Bohn et al., 1995; Drummond & Phillips, 2002). Internal consistency in the current sample was good at both timepoints (baseline $\alpha = .87$, post-manipulation $\alpha = .88$).

Alcohol consumption.

Alcohol consumption was measured via a taste test task, originally described by Caudill and Marlatt (1975), with modifications based on subsequent research (e.g., McGrath et al., 2016; Thomas et al., 2011). Participants were instructed that they will be asked to rate alcoholic beverages on a number of dimensions (e.g., taste, pleasantness) that will be used to inform design decisions for a future study. Participants were provided with three glasses of beer (Budweiser Light and Coors Light) in unmarked glasses (236.67 mL each for a total of 710mL) and instructed to consume as much of the beverages as they liked to inform their ratings. Budweiser Light and Coors Light were selected as they are likely to be generally palatable, are low in alcohol content, and are inexpensive. The first two glasses contained 236.67mL of Budweiser Light and Coors Light each, and the third was a combination of Budweiser Light and Coors Light. This procedure is similar to studies reporting mixing types of beer in a taste test task (e.g., Thomas et al., 2011) and was chosen to minimize waste of materials while still creating 3 different beverages for consumption. Participants had 30 minutes to consume the beverages. After 30 minutes, any remaining alcohol was measured. The dependent variable is the amount of alcohol consumed, which is computed by subtracting the amount of alcohol remaining from the total amount provided (710 mL).

Blood alcohol concentration.

An Alco-Sensor FST was used to measure blood alcohol concentration (BAC).

2.4 Procedure

Initial screening and eligibility.

Participants first completed a brief phone screening during which preliminary eligibility status (e.g., age, alcohol use status, liking for beer, medical/psychiatric conditions/medications contraindicated with alcohol consumption) was assessed after verbal consent to phone screening was obtained. Participants meeting initial eligibility criteria were scheduled for an in-person session; all in-person sessions were scheduled and took place in the afternoon. At the in-person session, participants underwent informed consent procedures with a trained research assistant. During the consent process, the study was described as investigating the relationship between cognitive processing among alcohol users. The TSST proceedings were described as an assessment of cognitive performance, and the purpose of the taste test task was described as being to collect qualitative data from participants to inform design decisions for a future study. Deception regarding the true purpose of the study was deemed necessary as participants' knowledge of the true purpose of the TSST (i.e., to induce a stress response) and the taste test task (i.e., to measure alcohol consumption) could substantially alter their behavior during those tasks. Those providing consent had their initial eligibility confirmed and were randomly assigned to either the experimental (TSST) or control condition.

Baseline measurements.

Participants then completed baseline questionnaires including demographics and the DMQ-R. The coping subscale of the DMQ-R assessed the frequency with which a participant endorses using alcohol to cope. Next, participants completed baseline measures of stress response (negative affect, MAP, heart rate).

Experimental manipulation.

Participants assigned to the experimental condition began the TSST procedures as described by Kirschbaum and colleagues (1993), with one minor modification to reduce participant burden. The original TSST (Kirschbaum et al., 1993) specifies that each of three phases lasts ten minutes, however recent research (e.g., Amlung & MacKillop, 2014) has demonstrated that a slightly shortened version of the TSST, wherein each of three phases lasts five minutes, is effective in inducing a stress response and was followed in the current study to reduce participant burden. *Anticipation phase:* First, a research assistant informed participants that they would be required to make a five-minute speech describing their qualifications for their dream job. The research assistant informed participants that their performance would be rated by psychologists on several dimensions. The research assistant also informed participants that they would have five minutes to prepare for the speech and set a timer for five minutes. The research assistant provided participants with a pen and paper to help prepare but informed participants that they would not be permitted to bring any notes into the interview. The research assistant then left the room. *Interview phase:* After the timer signaled the completion of the anticipation phase, the research assistant brought participants to a different room, with conference-room setup and a computer with a video recording application. Two confederates were seated in the room, and the research assistant introduced the confederates as psychologists who are trained to evaluate participants' verbal and nonverbal behavior during their speech and also directed participants' attention to the computer with the video recording application. The research assistant then left the room, and the confederates instructed participants to begin their speeches. The confederates were trained to remain stoic and provide no verbal or nonverbal (e.g., smiling, nodding) feedback during the speech. The confederates were provided with clipboards and bogus rating forms. Confederates were trained to make standardized notes during participants' speeches, so that the amount and/or content of the feedback was not reflective of a participant's actual performance. If participants ceased speaking before the five minutes had elapsed, a confederate prompted them to continue. *Mental arithmetic phase:* Confederates informed participants that the next part of the task is designed to assess cognitive functioning with a mental arithmetic task. Confederates instructed participants to begin subtracting 13 from 1022 and continue subtracting 13 from each subsequent number. Confederates were trained to correct participants if they made an error and instructed participants to begin again from the beginning. Participants were required to continue the mental arithmetic task for five minutes. *Control condition*: Participants in the control condition were given easily solvable anagrams to work on for 15 minutes. Each anagram consisted of a sentence in which one word, which was capitalized, was an anagram for which the letters could be rearranged to form a new word. Participants were instructed to select the correct new word that could be derived from the capitalized word from three multiple choice options.

Post-manipulation assessments.

Following the TSST (or control procedure), participants completed an immediate assessment of post-manipulation stress response, followed by the visual probe task to assess attention bias. A second post-manipulation assessment of stress response was administered, followed by administration of the alcohol craving measure and taste test task. Lastly, a final post-manipulation assessment of stress response was administered. Upon completion of study procedures, participants' blood alcohol content (BAC) was measured in 15-minute increments until a BAC of less than 0.03% was achieved. Finally, participants were debriefed about the true nature of the study, including the true purpose of the TSST and taste test task, compensated, and released. Table 1 presents the time course for the study session. Literature suggests that the TSST is effective in inducing a lasting, measurable stress response as evidenced by large effect sizes (Cohen's *d'*s = 1.0-1.3) on heart rate and MAP (Thomas et al., 2014) as well as sustained increases in MAP for up to 45 minutes following the TSST (Bacon & Thomas, 2013). When applied to research on alcohol outcomes, delays between TSST administration and measurement of alcohol outcomes of up to 30 minutes have been reported (Bacon & Thomas, 2013). Significant effects of the TSST on alcohol consumption have been reported when the taste test task occurred 15 (Magrys & Olmstead, 2015) and 20 minutes (de Wit et al., 2003) following the completion of the TSST. Therefore, the proposed study procedures were designed to occur well within the effective range of the TSST based on previously reported results. In the current study, the mean amount of time elapsed between conclusion of the experimental (or control) manipulation and measurement of alcohol craving was 11 minutes, and 16 minutes for measurement of alcohol consumption.

2.5 Data Analysis Plan

Preliminary Analyses

Descriptive statistics, including means and standard deviations (continuous variables) and frequencies (categorical variables) were calculated for all variables in SPSS version 26. Distributions were examined and tested for normality using a combination of visual inspection, examination of skewness and kurtosis statistics, and significance testing based on Kolmogorov–Smirnov tests of normality. Variables that were not normally distributed were transformed using square root and log transformations, transformed versions of the variables were examined for normality using the above procedures and substituted in analyses as appropriate. Outlier trials were excluded from attention bias calculations (e.g., trials with errors or reaction times of less than 200 milliseconds). Change scores were computed for the stress response variables (negative affect, heart rate, MAP) by subtracting the baseline value from the post-manipulation value, such that positive values reflect increases in stress response following the manipulation. A change score was computed for alcohol craving by subtracting the baseline value from the post-attention bias value, such that a positive score indicates an increase in alcohol craving following the experimental manipulation and assessment of attention bias. Bivariate associations were computed to examine relationships among relevant study variables and inform analyses. Independent samples *t*-tests were used to compare groups on baseline variables (e.g., age, stress response, coping motivation) to verify successful random assignment.

Aim 1

Separate ANCOVA's were used to test for differences between experimental and control groups on alcohol consumption and change in alcohol craving. Gender was entered as a covariate given the literature demonstrating gender differences in laboratory measures of alcohol consumption (for a review, see Graham et al., 1998).

Aim 2

Separate serial mediation models of the effect of the stressor on alcohol consumption and craving via the stress response and attention bias were specified using path analysis in Mplus version 8 (Muthén & Muthén, 1998-2017) with the model indirect command. To determine which of the assessments of stress response was used in the model, the relationship between the physiological and affective components of the stress response was examined, as well as the results of independent samples *t*-tests testing the effectiveness of the experimental manipulation in producing elevations in each of the measures of stress response. Separate models were run for change in alcohol craving and alcohol consumption. In each model, the DV was regressed on mediator 2 (attention bias), mediator 1 (stress response) and the IV (experimental condition). Mediator 2 was regressed on mediator 1 and the IV. Mediator 1 was regressed on the IV. Figure 1 depicts the theoretical model that was tested. Tests of significance for indirect effects were conducted using both Sobel first-order tests and 95% bootstrapped confidence intervals based on 10,000 resamples of the data, with no assumptions about the shape and/or distribution of the outcomes.

Exploratory aim

Exploratory moderated mediation models of the effect of a stressor on alcohol consumption and craving via the stress response and attention bias moderated by coping motivation for alcohol use were specified using path analysis in Mplus version 8 (Muthén & Muthén, 1998-2017). An interaction term was created by multiplying experimental condition by coping motivation for alcohol use. Coping motivation was retained as continuous and mean-centered prior to creating the interaction. Separate models were run for craving and consumption. In each model, the DV was regressed on mediator 2 (attention bias), mediator 1 (stress response), the moderator (coping motivation x experimental condition interaction) and the IV (experimental condition). Mediator 2 was regressed on mediator 1, the moderator and the IV. Mediator 1 was regressed on the moderator and IV. Figure 2 depicts the theoretical model that was tested. Tests of significance for indirect effects were conducted using 95% bootstrapped confidence intervals based on 10,000 resamples of the data, with no assumptions about the shape and/or distribution of the outcomes.

2.6 Power Analysis

Power analyses were conducted using a Monte Carlo simulation (Thoemmes et al., 2010). Power was estimated for Aim 2, the serial mediation model, as it required a larger sample size than Aim 1, the group comparison, and the moderated mediation model is considered exploratory. In a Monte Carlo simulation, parameters of a population model were estimated based on *a priori* theory and relevant literature. Next, via a resampling procedure, significance of each path and overall indirect (i.e., mediation) effects were estimated at a given sample size. For this study, path coefficients were estimated to be moderate in size, and α was set to .05. Power of .82 was achieved with a sample size of n = 120 in the simulation. However, the final sample size was n = 39 as data collection was halted due to the outbreak of the COVID-19 pandemic and subsequent restrictions on in-person interactions.

3. Results

3.1 Descriptive statistics

Descriptive statistics, including means and standard deviations (continuous variables) and frequencies (categorical variables) were calculated for all variables in SPSS version 26. Results are presented in Table 2. Log_{10} transformed versions of age and coping motivation variables were used in analyses. Variables with multiple categories (race and employment status) were collapsed into two categories (e.g., White/Non-White and student/non-student) due to low frequencies of many of the categories. Exclusion of outlier trials in the attention bias task resulted in exclusion of 1.62% of the individual trial data. This rate is comparable to that reported in similar literature utilizing the visual probe task (e.g., 4% reported by Field & Powell, 2007; 3.9% reported by Field & Quigley, 2009). Two participants' alcohol consumption data was excluded as it was invalid due to failure to understand the taste test task instructions (n = 1) and failing to meet the inclusion criterion of liking beer (despite meeting this criterion at the initial screening; n = 1).

3.2 Covariate testing

Covariates were determined based on *a priori* hypotheses and statistical tests of baseline differences between groups and associations with outcomes. Independent samples *t*-tests were conducted to examine baseline differences between the control (n = 20) and experimental (n = 19) groups on continuous variables (age, AUDIT-C score, coping motivation) and Chi-squared tests were conducted to examine baseline differences between groups on categorical variables (gender, race, student status). Results suggested that the groups did not differ on age (t (37) = 0.78, p = .44), gender (χ^2 (1, N = 39) = 0.64, p = .42), race (χ^2 (1, N = 39) = 0.03, p = .86), student status (χ^2 (1, N = 39) = 0.69, p = .41), coping motivation (t (37) = 0.37, p = .71), or AUDIT-C score (t (37) = 0.66, p = .51). Bivariate correlations were also examined to determine associations between relevant study variables and outcomes. Results suggest that age (consumption: r = .27, p = .11; craving: r = .11, p = .50), AUDIT-C score (consumption: r = .27, p = .11; craving: r = -.19, p = .26) and coping motivation (consumption: r = .003, p = .99; craving: r = -.06, p = .70) were not significantly associated with either alcohol consumption or alcohol craving. Therefore, only gender was included as a covariate as it was based on *a priori* hypotheses due to the substantial literature demonstrating gender differences in alcohol consumption (for a review, see Graham et al., 1998).

3.3 Manipulation checks

Manipulation checks were conducted via independent samples *t*-tests to compare change in stress response in the experimental versus control conditions. Results for MAP (t (37) = -1.22, p = .23) and heart rate (t (37) = 0.12, p = .91) suggest that the manipulation did not result in significant increases in MAP or heart rate in the experimental condition compared to the control condition. Analysis of effect sizes suggested a small-medium effect of the manipulation on MAP

(Cohen's *d* = 0.39) and a small effect of the manipulation on heart rate (Cohen's *d* = 0.04). Results suggested that the manipulation was effective in producing significant increases in negative affect (t (37) = -4.83, $p < .001$) in the experimental group (M = 0.45, SD = 0.42) compared to the control group (M = -0.10, SD = 0.28), and that the manipulation had a large effect on increase in negative affect (Cohen's *d* = 1.54).

3.3 Bivariate associations between relevant study variables

In addition to examining bivariate associations between relevant study variables to determine covariates, bivariate relationships between all relevant study variables were examined. Results can be found in Table 3. Age was significantly associated with AUDIT-C score (r = .41, p = .01); the positive, medium-sized correlation suggests that older participants endorsed more hazardous drinking patterns and a greater frequency of drinking to cope. Attention bias to alcohol cues was significantly associated with AUDIT-C score (r = .37, p = .02) and coping motivation (r = .33, p = .04); positive and medium-sized correlations suggest that participants endorsing more alcohol consumption and a greater frequency of drinking to cope demonstrated greater attention bias to alcohol cues. Additionally, increase in heart rate showed significant negative associations with attention bias to control cues (r = -.42, p = .01). The medium-sized correlation suggests that participants experiencing greater increases in heart rate evidenced less of an attention bias to control cues. Finally, an additional correlation between alcohol consumption and alcohol craving at the post-manipulation timepoint was computed to assess the relationship between the dependent variables. The correlation between alcohol consumption and change in alcohol craving is reported in Table 3, however the correlation between consumption and post-manipulation craving (instead of change in craving) was thought to be a better representation of the relationship between the dependent variables as there is no analogous change score for alcohol consumption. Results demonstrated a positive, but weak and non-significant association between alcohol consumption and craving (r = .18, p = .29).

3.4 Group differences in alcohol consumption and craving by experimental condition

Two separate one-way ANCOVAs were conducted to determine statistically significant differences between the experimental and control conditions on alcohol consumption and change in alcohol craving while controlling for gender. Results showed no significant difference in either alcohol consumption (F(1, 34) = 0.25, p = .62) or change in alcohol craving (F(1,36) = 0.22, p = .61) between experimental and control conditions. Analysis of effect sizes suggests small effects of the manipulation on both consumption (Cohen's d = 0.16) and change in craving (Cohen's d = 0.15). Gender was a significant covariate for alcohol consumption (F(1, 34) = 29.48, p<.001), but not change in alcohol craving (F(1,34) = 1.11, p = .30).

3.5 Serial mediation of stress response and attention bias

Figures 3 and 4 show the standardized coefficients from the path analysis of the serial mediation effect of stress response and alcohol attention bias on the relationship between experimental condition and alcohol consumption and change in alcohol craving, respectively. Table 4 presents additional coefficients for the total, total indirect, and direct effects as well as proportion mediated by the specific indirect effects for the serial mediation models as an estimate of effect size. The effect size estimates based on proportion mediated should be interpreted with caution, as it has been suggested that the proportion mediated effect size estimate is susceptible to bias in small samples (Fairchild, MacKinnon, Taborga & Taylor, 2009). Based on preliminary analyses of the effect of the experimental manipulation on the three different indicators of stress response (e.g., MAP, heart rate, and negative affect), negative affect was chosen as the representative indicator of stress response in the mediation analyses as it was the only indicator of stress response to evidence significant increases as a result of the experimental manipulation. Additionally, gender was controlled for in the model of alcohol consumption, but not change in craving, based on *a priori* hypotheses regarding gender differences in alcohol consumption and results from analyses of group differences in which gender was a significant covariate in the analyses of alcohol consumption, but not change in craving.

For alcohol consumption, the model accounted for 50.8% of the variance in alcohol consumption, 8.2% of the variance in alcohol attention bias, and 40.0% of the variance in change in negative affect. Contrary to hypotheses, analysis of indirect effects revealed no significant serial mediation effect of stress response and alcohol attention bias on the relationship between experimental condition and alcohol consumption (β = .02, *b* = 5.57, *SE* = 8.50, Sobel *z* = 0.66, *p* = .51, 95% CI [-0.43, 0.03]).

For change in alcohol craving, the model accounted for 5.3% of the variance in change in alcohol craving, 8.2% of the variance in alcohol attention bias, and 38.7% of the variance in change in negative affect. Contrary to hypotheses, analysis of indirect effects revealed no significant serial mediation effects of stress response and alcohol attention bias on the relationship between experimental condition and change in alcohol craving (β = .01, *b* = 0.07, *SE* = 0.20, Sobel *z* = 0.36, *p* = .72, 95% CI [-0.03, 0.04]).

3.6 Exploratory moderated mediation model of coping motivation

Exploratory moderated mediation models were specified to test coping motivation as a moderator of the serial mediation effect of stress response and alcohol attention bias on the relationship between experimental condition and alcohol consumption and change in alcohol craving. Gender was included as a covariate in the model for alcohol consumption, but not change in alcohol craving. Results indicated that the model for alcohol consumption accounted for 52.3% of the variance in alcohol consumption, 17.6% of the variance in alcohol attention bias, and 45.9% of the variance in change in negative affect. Analysis of the index of moderated mediation for the serial mediation effect suggested the moderated mediation effect was not significant (index = 1.41, *SE* = 17.22, Sobel z = 0.08, p = .94, 95% CI [-35.24, 27.62]). Results for the moderated mediation model of change in alcohol craving indicated the model accounted for 8.6% of the variance in change in alcohol craving, 17.4% of the variance in alcohol attention bias, and 41.5% of the variance in change in negative affect. Analysis of the index of moderated mediation suggested the moderated mediation effect was not significant (index = 0.02, *SE* = 0.51, Sobel z = 0.04, p = .97, 95% CI [-0.65, 1.21]).

4. Discussion

The aim of the current study was to replicate and extend literature on the relationship between exposure to a stressor and alcohol consumption by testing alcohol attention bias as a mediator of the stressor-alcohol relationship. Contrary to the study's primary hypotheses, there was not a significant difference in either alcohol consumption or change in alcohol craving resulting from exposure to a stressor, nor was there a significant serial mediation effect of stress response and alcohol attention bias on the relationship between exposure to a stressor and alcohol consumption/change in alcohol craving. The experimental manipulation demonstrated efficacy in inducing a partial stress response as evidenced by significantly greater increases in negative affect in the experimental versus control group. Results from the manipulation check analyses did not suggest significant effects of the experimental manipulation on either heart rate or MAP. And finally, there was no significant moderated mediation effect of coping motivation on the relationship between the stressor and alcohol consumption via the stress response and alcohol attention bias. Possible explanations for null findings, and considerations for future research, are considered below.

One possible explanation for null findings is the lack of statistical power to detect effects due to the small sample size, as data collection was discontinued due to the onset of the COVID-19 pandemic. Many of the analyses yielded effects in the expected direction (i.e., for MAP, group differences in consumption and craving, serial mediation and moderated mediation analyses) and descriptive differences were observed between groups in change in MAP (experimental $M = 4.42$, $SD = 7.01$; control $M = 1.10$, $SD = 9.75$), change in alcohol craving (experimental $M = 1.00$, $SD = 6.57$; control $M = -0.15$, $SD = 5.16$) and alcohol consumption (experimental $M = 570.22$, $SD = 146.25$; control $M = 566.74$, $SD = 182.98$). Specific to the moderated mediation analyses, the correlation between coping motivation and alcohol attention bias was significant, and its positive direction suggests that greater coping motivation was associated with greater alcohol attention bias. These results are consistent with previous literature reporting null findings that may be attributable to methodological confounds (e.g., Larsen et al., 2013; Mason et al., 2008) as well as conclusions drawn from a recent meta-analysis of laboratory studies of the effects of stressors on alcohol outcomes highlighting lack of statistical power as a possible explanation for null findings in previously published research (Bresin et al., 2018). Alternative explanations, as well as explanations for results not in the anticipated direction, are considered below in order to guide future research on the relationship among stressors, attention bias, and alcohol use.

The direction of the effect was not in the expected direction for heart rate, which is similar to some studies that have reported significant increases in negative affect and MAP, but not heart rate following exposure to a stressor (Fox et al., 2007). Some research suggests that heart rate may peak *during* exposure to a stressor, as demonstrated by studies using continuous measurement of heart rate (Fox et al., 2007; Kirschbaum et al., 1993). Heart rate in the current study was assessed immediately following exposure to a stressor but nonetheless, it may be necessary to assess heart rate continuously throughout exposure to a stressor to best capture elevations in heart rate associated with a stress response.

In addition, continuous assessment of heart rate would allow for calculation of heart rate variability (HRV), namely the variability in time elapsed between two successive heartbeats, as well as heart rate. Elevations in heart rate are reflective of the increased physiological arousal that results from activation of the sympathetic nervous system in response to stressors. Conversely, an individual’s ability to activate the parasympathetic nervous system to offset the sympathetic nervous system and decrease physiological arousal following exposure to a stressor is dependent on the ability to vary heart rate (Appelhans & Luecken, 2006). Research suggests that HRV has been associated with an individual’s affective response to a stressor, as well as use of coping strategies; decreased HRV has been associated with higher negative affect in response to stressors, and greater use of maladaptive coping strategies (Appelhans & Luecken, 2006). Future research should consider the capability to assess heart rate throughout exposure to a stressor, which would better allow researchers to capture elevations in heart rate and allow for the calculation of HRV, if using heart rate as an indicator of the physiological component of the stress response.

It is also possible that the modifications to the original TSST (e.g., shortened phases from 10 minutes each to 5 minutes each) reduced the efficacy of the manipulation in inducing a stress response. The decision to shorten the phases was supported by both previous research using shortened phases (e.g., Amlung & MacKillop, 2014; Magrys & Olmstead, 2015), and its demonstrated efficacy in pilot testing conducted prior to the current study. The procedure used in the current study is more involved than similar studies utilizing only one of the three phases of the TSST (e.g., Field & Powell, 2007; Field & Quigley, 2009; de Wit et al., 2003), all of which reported significant positive effects of the stressor on alcohol consumption. Nonetheless, researchers investigating the stressor/alcohol relationship should consider the use of modified (i.e., shortened) versions of the TSST, and pilot test modifications when possible.

Although the overall indirect effect was in the anticipated direction, examination of the direction of effects among variables in the serial mediation model in combination with results from the analysis of the effect size of the manipulation on negative affect suggests that the overall positive indirect effect may have been driven by the large positive effect of the stress manipulation on negative affect. Not only was the effect of the manipulation on negative affect large (Cohen's $d = 1.54$), the coefficients representing the effects of stress response on alcohol attention bias and alcohol attention bias on alcohol outcomes were both negative, albeit nonsignificant. As such, additional explanations for null findings are considered as well.

One possible explanation for null findings of the serial mediation of stress response and alcohol attention bias concerns the operationalization and measurement of attention bias. In particular, the number of trials administered during the visual probe task may have limited its reliability in the current study. Although the number of trials was consistent with previous research on alcohol attention biases (e.g., Field & Powell, 2007; Miller & Fillmore, 2009), other areas of research using the visual probe task to assess non-alcohol attention biases (e.g., attention bias toward threat stimuli) have reported administrations of substantially more trials (e.g., 560 trials; Hedger, Garner & Adams, 2019). The current study may have been limited in its ability to administer a visual probe task with 500 or more trials due to the need to complete this and other assessments within the constraint imposed by the duration of the stress response, however it is possible that the number of trials was not sufficient to reliably to capture alcohol attention biases elicited by the stress response.

In addition to the possible effect of the number of trials on the visual probe task's reliability in the current study, recent research has highlighted inconsistency in assessments of the reliability of attention bias measured via the visual probe task (e.g., Jones et al 2018). Researchers have investigated modifications to the visual probe task (Christiansen et al., 2015; Erceg-Hurn & Mirosevich, 2008; Price et al., 2015; Waechter et al., 2014) as well as alternative tasks to assess attention bias (e.g., Pennington et al., 2020) to improve the reliability of the assessment of attention bias. Conclusions from this line of research should be incorporated into future research on attention bias in order to maximize the reliability of its measurement.

Alternatively, recent research has considered a different conceptualization of attention bias as a construct that is highly state-dependent and is easily influenced by a number of internal and external factors, even within a single administration of the task that may account for inconsistency in assessments of the reliability of the visual probe task (Hedge et al., 2018; Kruijt et al., 2016). Early research has demonstrated support for a dynamic conceptualization of attention bias and for the role of internal factors such as negative affect and anxiety in producing more highly variable profiles of attention characterized by phases or "bursts" of attention bias among individuals identified with specific phobias (Zvielli et al., 2015), Posttraumatic Stress Disorder (Schäfer et al., 2016) and high in trait-level anxiety (Cox et al., 2018) compared to healthy control participants. Future research should aim to examine this alternative dynamic conceptualization of attention bias among alcohol-using populations.

In considering additional explanations for null findings of the moderated mediation analyses, we examined the characteristics of the sample in relation to the level of coping motivation, in comparison to similar studies. The level of coping motivation observed in the current sample is notably higher (*M* = 2.09, *SD* = 0.90, range: 1 - 4.6) than that reported in studies of non-hazardous alcohol users (e.g., *M* = 1.60 reported by Cooper et al., 1994; *M* = 1.61 reported by Kuntsche et al., 2008; *M* = 1.82 reported by O'Hara, Armeli & Tennen, 2014). In order to directly compare the level of coping motivation to similar studies of hazardous drinkers reporting median rather than mean statistics, we calculated the median level of coping motivation in our sample (median = 2.0) and found it somewhat lower than studies reporting on similar samples of hazardous drinkers (e.g., median = 2.4 reported by Field & Powell, 2007; median = 2.4 reported by Field & Quigley, 2009).

We also examined the level of coping motivation in relation to levels of the other three motivational factors in our sample, and found that participants reported more frequent social motivation (*M* = 3.24, *SD* = 1.01) and enhancement motivation (*M* = 2.85, *SD* = 0.90) for alcohol use compared to coping motivation. Therefore, despite reporting more frequent coping motivation compared to non-problem drinkers, it is possible that the sample was overall low in coping motivation compared to hazardous drinkers, or that other motivational factors may have been more influential in driving hazardous drinking behavior compared to coping motivation. Future research on negative reinforcement models, and in particular research investigating the role of cognitive processes in negative reinforcement models should continue to investigate coping motivation as a potential moderating factor, with particular consideration of the motivational charateristics of the sample overall, and the relationship among all four motivational factors.

A final possible explanation for null findings related to sample characteristics is preference for alcoholic beverage. All participants were required to report “liking beer” as an inclusion criterion for the study, a procedure based on similar studies using the taste test task to assess alcohol consumption (e.g., Merrill & Thomas, 2013). However, it is possible that this procedure allowed for variability in the degree to which participants liked beer which could have influenced results. Similar studies have offered participants their preferred beverage, as assessed prior to participation, for the taste test task (e.g., Kidorf & Lang, 1999) or included a variety of types of alcoholic beverages during the taste test task (e.g., Larsen et al., 2013). Future research should consider protocols that allow for greater choice and/or consumption of preferred beverage when utilizing assessments of ad libitum alcohol consumption such as the taste test task.

Overall, the current study has both strengths and limitations. Strengths include the inclusion of an ecologically valid outcome measure (alcohol consumption) that extends previous research, assessments of physiological and affective components of the stress response, and tests of a novel mechanism in the stressor-alcohol relationship (alcohol attention bias). Limitations include small sample size, as data collection was discontinued due to the onset of the COVID-19 pandemic, which may have decreased statistical power to detect significant effects. Additionally, the reliability of the visual probe task may be a limitation, although reliability of the visual probe task in the current study could not be assessed, and low coping motivation of the sample overall. In spite of limitations, the current study offers several directions for future research on the role of cognitive processing in the development and maintenance of problematic alcohol use. Better understanding of how problematic alcohol use develops and is maintained may guide intervention that may help ameliorate its detrimental effects on individual and public health.

Table 1.
Timeline of study procedures

Procedure	Duration	Time point
Informed consent	15 min	n/a
Baseline questionnaires (demographics, drinking motivation, baseline craving)	5 min	-5
Baseline stress response	2 min	-2
Experimental manipulation	15 min	0
Post-stress response	2 min	post
Attention bias	5 min	+2
Stress response	2 min	+7
Craving	1 min	+9
Taste test task	30 min	+10
Stress response	2 min	+30

Table 2.
Descriptive statistics for relevant study variables in overall sample and by condition

	Overall sample (*n*=39)		Control (*n*=20)		Experimental (*n*=19)	
	M(%)	*SD*	*M* (%)	*SD*	*M*(%)	*SD*
Age	30.38	12.42	31.45	11.92	29.26	13.14
Gender (% female)	30.80	-	25.00	-	36.84	-
Race (% White)	56.4	-	55.00	-	57.89	-
Employment status (% student)	43.6	-	50.00	-	36.84	-
AUDIT-C total	7.18	2.11	7.40	1.76	6.95	2.46
DMQ Coping	2.09	0.90	2.17	1.00	2.00	0.79
MAP change	2.72	8.59	1.10	9.75	4.42	7.01
Heart rate change	0.05	5.19	0.15	5.68	0.05	4.77
Negative affect change	0.17	0.45	-0.10	0.28	0.45	0.42
Alcohol attention bias (ms)	1.13	15.32	4.98	13.72	-2.92	16.21
Control attention bias (ms)	-1.60	26.30	-0.07	32.70	-3.35	18.02
Alcohol craving change	0.41	5.84	-0.15	5.16	1.00	6.57
Alcohol consumption (mL)	568.43	163.84	566.74	182.98	570.22	146.25

Note. Stress response change variables (MAP, heart rate, negative affect) represent change from baseline to immediately post stress induction. Positive scores indicate increases in MAP, heart rate, and negative affect from baseline to post-manipulation. Control attention bias represents attention bias toward control cues. Alcohol craving change represents change in craving from baseline to post manipulation and attention bias task; positive scores represent increase in alcohol craving. N = 37 (control group n=19, experimental group n=18) for alcohol consumption statistics due to exclusion of 2 participants' invalid consumption data.

Table 3.
Bivariate associations between relevant study variables

	Age	AUDIT-C	DMQ-R Coping	Negative affect change	MAP change	HR change	Alcohol AB	Control AB	Alcohol Craving Change	Alcohol Consumption
					r					
Age	-	.41*	.28	-.17	.10	-.002	.07	-.04	.11	.27
AUDIT-C		-	.15	-.17	.09	-.19	.37*	.15	-.19	.27
DMQ-R Coping			-	-.17	.03	-.10	.33*	.03	-.06	.003
Negative affect change				-	.19	-.27	-.25	.12	.22	-.17
MAP change					-	.22	-.11	.01	-.02	.20
Heart rate change						-	-.21	-.42**	-.01	.21
Alcohol attention bias							-	.23	-.11	-.15
Control attention bias								-	.23	-.26
Alcohol craving change									-	-.22
Alcohol consumption										-

Note. *N*=39, *N*=37 for associations with alcohol consumption. Stress response change variables (MAP, heart rate, negative affect) represent change from baseline to immediately post stress induction. Positive scores indicate increases in MAP, heart rate, and negative affect from baseline to post-manipulation. Control attention bias (AB) represents attention bias toward control cues. Alcohol craving change represents change in craving from baseline to post manipulation and attention bias task; positive scores represent increase in alcohol craving.
* $p < .05$
** $p < .01$
*** $p < .001$

Table 4.
Serial mediation effects of stress response and alcohol attention bias

Predictor	Mediator 1	Mediator 2	Outcome	Total indirect effect (SE)	Direct effect (SE)	Total effect (SE)	Proportion mediated
Condition	Stress response	Alcohol AB	Consumption	-13.78 (32.33)	35.75 (49.35)	21.96 (38.95)	6.5%
Condition	Stress response	Alcohol AB	Craving	1.95 (1.51)	-0.80 (2.32)	1.15 (1.84)	2.5%

Note. *N*=39 for model of alcohol craving, *N*=37 for model of alcohol consumption. Condition is experimental condition, coded as 0=control, 1=exposure to stressor. Stress response is change in negative affect from baseline to post-manipulation. Alcohol AB is attention bias to alcohol cues. Consumption is alcohol consumption; craving is change in alcohol craving from baseline to post-manipulation. Proportion mediated represents proportion of the total effect that is accounted for by the specific indirect effects. All estimates are unstandardized. Gender was included as a covariate in the model of alcohol consumption.
* $p < .05$
** $p < .01$
*** $p < .001$

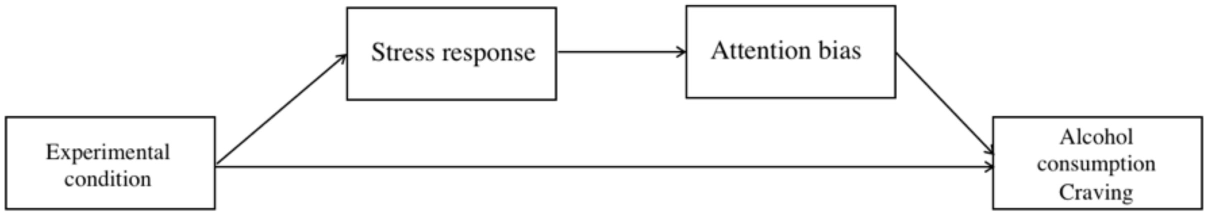

Figure 1. Theoretical serial mediation model of the effect of a stressor on alcohol consumption via the stress response and attention bias to alcohol cues.

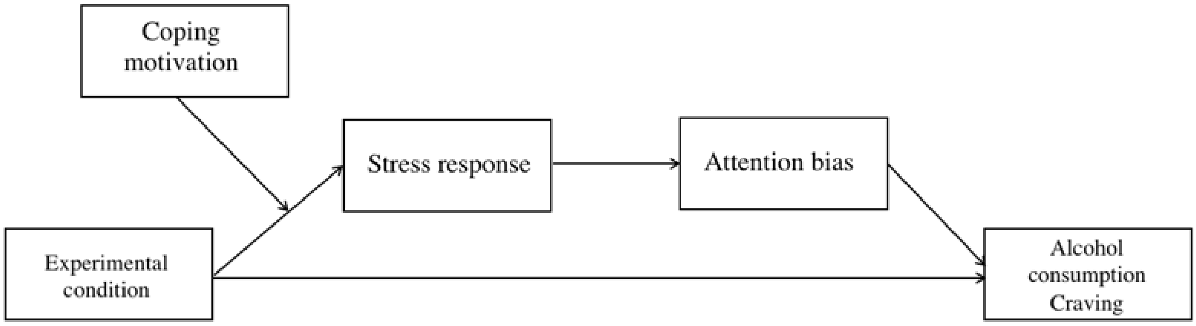

Figure 2. Theoretical moderated mediation model of the effect of a stressor on alcohol consumption via the stress response and attention bias to alcohol cues, moderated by coping motivation.

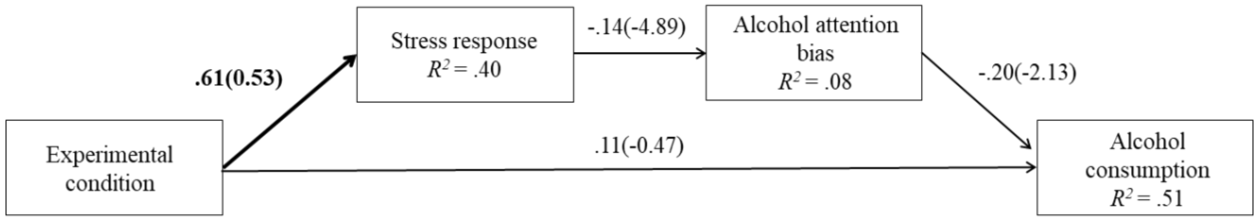

Figure 3. Serial mediation effect of stress response and alcohol attention bias on alcohol consumption. Gender was included as a covariate but omitted from the figure for simplicity. Coefficients are standardized (unstandardized). Model Fit: χ^2 (26, *N* = 37) = 26.53, *p* = .43; AIC = 1580.42; BIC(adjusted) = 1546.74; RMSEA = .02 (.00, .13); CFI = 0.99; TLI = 0.98; SRMR = .12. Significant paths/coefficients are bolded.

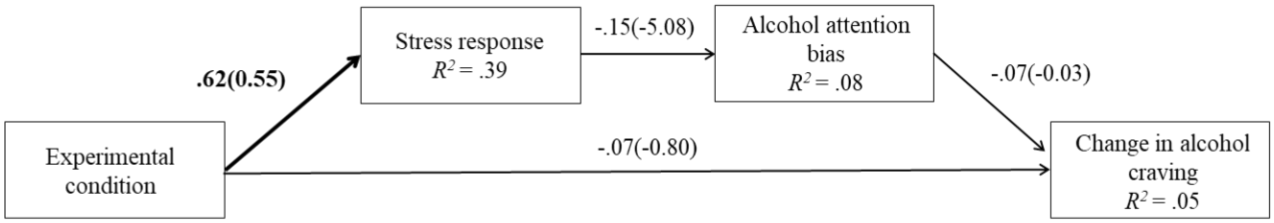

Figure 4. Serial mediation effect of stress response and alcohol attention bias on change in alcohol craving. Coefficients are standardized (unstandardized). Model Fit: χ^2 (30, N = 39) = 52.47, p = .01; AIC = 1654.08; BIC(adjusted) = 1621.86; RMSEA = .14 (.07, .20); CFI = 0.45; TLI = 0.34; SRMR = .15. Significant paths/coefficients are bolded.

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