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## Access to Environmental Reward Mediates the Association between Posttraumatic Stress Symptoms and Alcohol Problems and Craving

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### Abstract

Symptoms of posttraumatic stress (PTS) show significant comorbidity with alcohol use, but little is known about the mechanisms that might account for this comorbidity. Deficits in reward functioning have long been implicated in alcohol misuse and more recently in PTS reactions, but no study has examined whether reward deprivation may serve as a transdiagnostic risk factor for comorbid PTS-alcohol misuse. The current cross-sectional study sought to test the behavioral economic hypothesis that reward deprivation would be related to both PTS symptoms and alcohol problems, and would mediate the relation between PTS symptoms and alcohol problems in college students. We recruited a diverse sample of urban college students ( $N = 203$ ,  $M_{\text{age}} = 21.5$  years,  $SD = 5.5$ ; 79.5% female; 56.8% White, 28.1% Black, .9% Asian, 9.8% Multiracial) who endorsed both alcohol use and PTS symptoms. Reward deprivation (lack of access to, and ability to experience reward) was related to alcohol problems, and a lack of access to reward was related to PTS symptoms. Furthermore, *reward access* mediated the relation between PTS symptoms and alcohol problems and craving, after controlling for alcohol use, age, gender, and race. These data provide preliminary support for behavioral economic models of alcohol comorbidity and suggest that treatments for combined PTS-alcohol misuse should attempt to reduce barriers to accessing natural rewards.

### Keywords

PTSD; behavioral economics; reward deprivation; college student drinking

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SFA and JGM formulated the study question and collected the data. SFA, MTL, and KES wrote the first draft. MMM and MTL provided expertise in PTSD. KJJ and JGM provided expertise in reward. All authors contributed to subsequent versions of the manuscript. All authors have approved of the final draft of the manuscript.

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Despite evidence of recent population-level reductions in college student drinking (Hingson, Zha, & Smyth, 2017), college students remain a high-risk group for alcohol misuse. In the past month, 63% endorse drinking any alcohol, 39% report heavy episodic drinking, and 13% report drinking more than 10 drinks in one occasion in the past two weeks (Hingson et al., 2017; Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2014). Although small to moderate amounts of alcohol often have positive effects, including social facilitation (Sayette et al., 2012), heavy drinking can result in a range of negative consequences such as hangovers, academic impairment, blackouts, driving after drinking, and accidents/injuries (Arria, Caldeira, Bugbee, Vincent, & O'Grady, 2013; Hingson et al., 2017).

Among college students, heavy alcohol misuse is also tied to symptoms of posttraumatic stress (Dennhardt & Murphy, 2011; Pedrelli, Collado, Shapero, Brill, & MacPherson, 2016). For example, college women with a history of sexual victimization demonstrated stronger urges to drink on days when posttraumatic stress (PTS) symptoms were elevated (Kaysen et al., 2014). Another longitudinal study showed heightened risk for alcohol-related negative consequences among students endorsing PTS symptoms and past-month alcohol use over the course of one year (Read et al., 2012). Further, individuals with PTSD were found to be more likely to experience alcohol-related problems as a result of "pregaming" (consuming alcohol prior to attending an event at a bar or party) when compared to those without trauma experiences or PTSD (Radomski, Blayney, Prince, & Read, 2016). PTS symptoms are also linked to alcohol craving (Coffey et al., 2006), and one study found that craving mediated the relation between PTS symptoms and alcohol-related problems among college students (Tripp et al., 2015a). Individuals with PTSD and co-occurring alcohol use disorder are likely to experience more severe symptoms of both conditions, as well as more severe health-related problems, including depression (Blanco et al., 2013; Brown, Stout, & Mueller, 1999; Ouimette, Goodwin, & Brown, 2006). This is particularly relevant for college students, as up to 84% have experienced at least one traumatic event in their lifetime, and one third experience four or more traumatic events (Vrana & Lauterbach, 1994). Further, recent research has demonstrated that between 9 and 13% of college students may meet screening criteria for PTSD (Fortney et al., 2016; Read, Ouimette, White, Colder, & Farrow, 2011). Thus, PTS is common in college students and, even in the absence of a formal PTSD diagnosis, can result in dysregulated drinking patterns characterized by elevated craving and alcohol-related consequences.

The dominant theory explaining this comorbidity is Khantzian's *self-medication hypothesis*, which states that individuals who experience high levels of negative affect may drink in order to alleviate or cope with these symptoms (Khantzian, 1997). Although this model has received extensive empirical support, one limitation is that it fails to account for the prominent positive reinforcing effects of alcohol among individuals with significant comorbidity (Dennhardt, Murphy, McDevitt-Murphy, & Williams, 2016; Lembke, 2012). Behavioral economic theory may be able to provide additional insight into the relation between PTS symptoms and alcohol misuse. Behavioral economic theory assumes that decisions to use alcohol and other drugs are a function of the benefit/cost ratio of substance use in relation to the benefit/cost ratios of other available activities. In this "reinforcer pathology" model, alcohol misuse results from ongoing interactions between physiological factors (e.g., subjective response to alcohol and elevated negative affect), environmental

factors (e.g. low availability of alternative rewards, high availability of alcohol/drugs, social contexts that reinforce alcohol/drug use, or life events that cause stress and disrupt access to environmental reward), and a consistent preference for immediate relative to delayed rewards. Together, these factors increase the reinforcing value of alcohol and other drugs relative to alternatives (Bickel et al., 2017; Tucker, Vuchinich, & Rippens, 2002; Vuchinich & Heather, 2003).

Consistent with this perspective, several studies suggest that behavioral economic indices of alcohol reward value may help to explain the relation between PTS and other negative affect symptoms and alcohol misuse. Alcohol demand is an individual difference variable representing one's valuation for alcohol, operationalized as the consumption of alcohol as a function of changes in price (Murphy & MacKillop, 2006), and laboratory studies suggest that demand increases acutely in response to alcohol or stress cues (Amlung & MacKillop, 2014; MacKillop et al., 2010; Owens, Ray, & MacKillop, 2015). One study found that alcohol demand mediates the relation between PTS symptoms and alcohol misuse among college students (Tripp et al., 2015a). In another study, behavioral economic demand also mediated the relation between depressive symptoms and alcohol-related problems, suggesting that states of negative affect may increase risk for alcohol-related problems through increases in substance reward value (Soltis, McDevitt-Murphy, & Murphy, 2017). This same study found that consideration of future consequences, or the degree to which one considers the future while making present decisions, also mediates this relation.

The Reward Probability Index (RPI; Carvalho et al., 2011), a measure of reward deprivation originally intended for use among depressed individuals, has recently been applied to alcohol misuse. The RPI includes subscales measuring both access to environmental reward and the ability to experience reward. Joyner and colleagues (2016) found that *access to environmental reward*, but not the ability to experience reward, predicted a greater risk for alcohol use disorder and alcohol-related problems among college student heavy drinkers. The authors suggest that those with diminished access to environmental reward may have poor access to recreational and educational resources due to poverty, and in some cases, may lack the social skills or self-regulatory capacity to engage in or to take advantage of opportunities to participate in rewarding social, leisure, or academic/community activities. This lack of stimulation in the environment from other activities may increase the relative value of alcohol to alleviate boredom and fill the reward void. For those experiencing traumatic events, PTS symptoms may also be associated with diminished availability of alternative substance-free reinforcements, both because PTS symptoms may be more likely to occur in environments that are devoid of natural rewards and because of PTS-related avoidance. The diagnostic criteria for PTSD include a cluster of avoidance symptoms, denoting behavioral and cognitive avoidance of trauma-related triggers. This avoidance pattern could have the effect of reducing the individual's access to reward that was more readily accessible before the traumatic event, including social support and substance-free activities. Diminished access to reward may in turn increase the relative valuation of alcohol and contribute to increased alcohol consumption, problems, and craving (Murphy et al., 2013).

Anhedonia, or ability to experience reward, has also been connected to PTSD and substance misuse and is represented with the other subscale in the RPI. Those with a history of PTSD show a blunted response to reward during behavioral tasks in samples comparing those with and without PTSD (Elman et al., 2005; Kalebasi et al., 2015). Further, one study has shown that PTSD is associated with lower self-reported expectancy of reward among male Vietnam veterans (Hopper et al., 2008), and a systematic review suggests that PTSD is related to lower hedonic response to reward (Nawijn et al., 2015). This is noteworthy given other prospective research linking blunted response to drug-free rewards with more chronic drug misuse (Lubman et al., 2009; Meshesha, Pickover, Teeters, & Murphy, 2017). This may relate to the significant anhedonia, or loss of the ability to experience pleasure due to impairment in reward functioning typically associated with individuals with PTSD.

## Current Study

A recent review concluded that PTS symptomatology seems to be associated with reward deprivation, which is in turn associated with greater alcohol misuse (Vujanovic, Wardle, Smith, & Berenz, 2016), but this model has yet to be tested empirically. Consistent with the NIH transdiagnostic Research Domain Criteria (RDoC) framework, reward deprivation may be a transdiagnostic risk factor for both PTSD and alcohol misuse that results from the combination of an overactive negative valence system and an underactive positive valence (environmental approach) system for natural (substance-free) rewards, leading to an overvaluation of alcohol. Thus, the current study evaluates reward deprivation (availability and experience of reward in one's immediate environment) as a risk factor for both PTS symptomatology and alcohol misuse and its role as a mediator between PTS symptoms and alcohol misuse. We hypothesize that access to and ability to experience reward will mediate the relations between PTS symptomatology and three central elements of alcohol misuse (alcohol consumption, craving, and problems).

## Methods

### Participants

Participants were 203 undergraduate college students who had at least one day of alcohol use in the past month and reported a trauma consistent with DSM-V Criterion A. This subset of data was taken from a larger dataset of college students ( $N = 595$ ). All students were recruited through an online psychology research participation platform in a large public university system in the southern United States (79.8% women; average age 21.5,  $SD = 5.5$ , range = 18–56). This university serves a diverse student population including many nontraditional students; 48 (21.6%) were age 23 or older, and the sample was 56.7% White, 28.1% Black, .9% Asian, and 9.8% Multiracial. Additionally, 4.5% reported their ethnicity as Latino. Participants completed self-report measures online and received course credit for completing the survey. The university's Institutional Review Board approved all procedures.

### Measures

**PTS Symptoms**—The 20-item PTSD Checklist for the DSM-5 (PCL-5; Weathers et al., 2013) was used to assess posttraumatic stress symptoms. The PCL-5 provides a definition

and examples of Criterion A traumas and asks participants to respond if they had experienced a similar event. Participants were asked to rate on a scale of 0 (*Not at all*) to 4 (*Extremely*) how much in the past month they were bothered by each of a list of 20 symptoms of PTSD. Example items include: “Feeling very upset when something reminded you of the stressful experience?” and “Feeling jumpy or easily startled?” Item scores were summed to produce a severity score, which ranges from 0 to 80. Scores of 33 or greater indicate problematic PTS symptoms (Weathers et al., 2013). The PCL-5 parallels the DSM-5 criteria for PTSD (American Psychiatric Association, 2013) and has demonstrated strong reliability and validity in a sample of college students (Blevins et al., 2015). Internal consistency ( $\alpha$ ) in the current sample was .96.

**Alcohol Consumption**—Participants provided an estimate of the total number of standard drinks they consumed each day during a typical week in the past month on the Daily Drinking Questionnaire (DDQ; Collins, Parks, & Marlatt, 1985). Consumption on each day is summed to estimate typical drinks per week. The DDQ has been widely used in the college drinking literature (Geisner, Varvil-Weld, Mittmann, Mallett, & Turrissi, 2015).

**Alcohol Problems**—The Brief Young Adult Alcohol Consequences Questionnaire (B-YAACQ) is a 24-item Yes/No self-report measure of alcohol-related problems experienced over the past month. Examples of items include: “I have spent too much time drinking” and “I have felt very sick to my stomach or thrown up after drinking.” Each item is summed, and the sum is multiplied by two to create a total score. The BYAACQ has good test-retest reliability (Kahler, Strong, & Read, 2005). Cronbach’s alpha in the current sample was .89.

**Alcohol Craving**—The Penn Alcohol Craving Scale (PACS; Flannery, Volpicelli, & Pettinati, 1999) is a 5-item self-report measure of past week frequency, intensity, and duration of alcohol craving, as well as ability to resist alcohol. The measure uses a Likert-type scale from 0 (*0 times during the past week/None at all/Not difficult at all/Never had the urge to drink*) to 6 (*More than 40 times during the past week or more than 6 times per day/Strong urge and would have drunk alcohol if it were available/More than 6 hours/ Would not be able to resist/Had the urge to drink nearly all of the time*). Examples of items include: “During the past week, how often have you thought about drinking or about how good a drink would feel?” and “how difficult would it have been to resist taking a drink if you had known alcohol was in your house?” Items are summed to generate a total past-week craving score. The PACS has demonstrated excellent evidence for construct validity (Flannery et al., 1999). Cronbach’s alpha in the current sample was .84.

**Reward Deprivation**—The Reward Probability Index (Carvalho et al., 2011) was used to measure ability to experience reward and the environmental availability of reward (*Range* = 20 – 80). The RPI consists of two subscales: Reward Probability (referred to as ability to experience reward throughout this paper) and Access to Environmental Reward (also called the “environmental suppressors” subscale). The Reward Probability subscale (*Range* = 11 – 44) assesses the subjective sense of pleasure or accomplishment experienced when rewards are obtained (e.g., “There are many activities that I find satisfying”; “I have many interests that bring me pleasure”; “I have the abilities to obtain pleasure in life”), with higher scores.

The Access to Environmental Reward subscale (Range = 9 – 36) assesses obstacles to obtaining or engaging in rewarding activities (e.g., “I have had many unpleasant experiences”; “Changes have happened in my life that have made it hard to find enjoyment”; “People have been mean or aggressive towards me”). Responses are scored on a Likert-type scale from 1 (*Strongly Disagree*) to 4 (*Strongly Agree*). Higher total scores on both subscales indicate a higher degree of access to and experience of reward. Both subscales demonstrated good internal consistency in the current sample ( $\alpha$ s = .84–.86). The RPI has also demonstrated strong evidence for convergent and discriminant validity (Carvalho et al., 2011).

## Data Analysis Plan

Outliers (values 3.29 standard deviations outside of the mean) were identified and corrected to one unit above the next most extreme score (Tabachnick & Fidell, 2013). Assumptions of normality were checked for all variables. Alcohol consumption was slightly kurtotic (4.73) and was corrected with a square root transformation. All other variables met assumptions of normality. Covariates were selected using a two-step process. First, we identified theoretically relevant variables within the literature that have previously been noted as important factors in PTSD and alcohol misuse. We selected five variables from our dataset: socioeconomic status, gender, race, alcohol consumption, and age. Second, covariates were required to have a relation with both the independent and the dependent variables to be included within the model. Correlations revealed that only alcohol consumption was significantly associated with both our independent and dependent variables. Thus, we only controlled for alcohol consumption in the reported model<sup>1</sup>.

We first examined bivariate correlations among key study variables. To test our hypothesis, we tested six mediation models using Haye’s PROCESS macro in SPSS v24. We examined each independent variable (ability to experience reward and access to environmental reward) as separate mediators of the relation between PCL-5 scores and alcohol consumption, craving, and related problems. For models examining alcohol-related problems or craving, we controlled for alcohol consumption.

## Results

### Descriptive Statistics and Bivariate Correlations

Descriptive statistics for the sample can be found in Table 1. Participants drank, on average, 7.33 alcoholic drinks per week ( $SD = 9.05$ ) and experienced 8.47 alcohol-related problems in the past month ( $SD = 8.85$ ). The average PTS symptom severity rating was 22.29 ( $SD = 18.34$ ), and 31% exceeded the clinical cut-off point (33) (Weathers et al., 2013). An independent samples  $t$ -test revealed that males reported more drinks per week ( $M = 9.66$ ,  $SD = 9.09$ ) than females ( $M = 6.27$ ,  $SD = 6.06$ ;  $t(200) = 2.76$ ,  $p < .01$ ); there were no other gender differences among study variables. Table 2 presents correlations among study variables. Caucasian participants drank more (Caucasian:  $M(SD) = 7.64(6.67)$ ; Minority:

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<sup>1</sup>We also examined models containing all potential covariates. The results were nearly identical to those reported in the manuscript, and no analysis changed significance.

$M(SD) = 6.03 (7.03)$ ;  $t(201) = -2.31, p = .02$ ) reported more problems, (Caucasian:  $M(SD) = 10.02 (9.46)$ ; Minority:  $M(SD) = 6.39 (7.51)$ ;  $t(192.07) = -2.89, p < .01$ ), and scored lower on the reward probability factor (Caucasian:  $M(SD) = 33.73 (4.08)$ ; Minority:  $M(SD) = 35.38 (5.78)$ ;  $t(142.21) = 2.23, p = .03$ ) than non-White minorities. Alcohol consumption, alcohol problems, craving, and endorsement of PCL scores were all correlated in the expected directions, and these variables correlated negatively with the access to environmental reward subscale, such that low access to environmental reward were related to greater endorsement of drinking, problems from drinking, craving, and PTS (See Figures 1 and 2). The reward probability subscale (experience of reward) only demonstrated significant correlations with drinks per week and craving in the expected direction. Age was negatively correlated with PTS symptoms.

### **Reward Deprivation as a Mediator of the Relation between PTS Symptoms and Alcohol Consumption, Craving, and Problems**

In models that included the reward probability subscale and access to environmental reward subscale separately, neither variable mediated the relation between PCL score and typical drinks per week (Table 2). Next, we examined RPI subscales as mediators of the relation between PTS symptoms and alcohol craving after controlling for drinks per week. In the separate mediator models, access to environmental reward subscale was a significant mediator; the reward probability subscale was not. Finally, we examined RPI subscales as mediators of the relation between PCL score and alcohol-related problems after controlling for typical drinks per week. Only the access to environmental reward subscale was a significant mediator (Figure 1). Access to environmental reward indirectly accounted for 52% and 39% of the effect of PCL score on alcohol craving and alcohol-related problems, respectively<sup>2</sup>.

### **Discussion**

Alcohol misuse is often exacerbated by traumatic experiences (e.g. sexual assault, childhood trauma, exposure to other violence or natural disasters), which are also highly prevalent among urban public university students (Black et al., 2011; Craner, Martinson, Sigmon, & McGillicuddy, 2015). Although many studies have examined these relations in the context of self-medication, this study is one of the first to explore the role of reward experience and environmental access to reward as a mechanism that might account for the association between PTS and alcohol consumption, craving, and problems.

Over a third of our screening sample reported both alcohol consumption and a trauma experience, suggesting high rates of trauma and use in this population. We found that all three alcohol variables were positively correlated with PTS symptom severity. This is consistent with prior research that has demonstrated similar relationships between PTSD and alcohol misuse (Read, Wardell, & Colder, 2013). Further, PTS symptoms were negatively associated with access to environmental reward. Although previous research has found that PTSD is associated with blunted reward response (anhedonia; Elman et al., 2005; Nawijn et

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<sup>2</sup>Although the small number of men ( $n = 36$ ) in our sample precluded formal tests of gender interactions, we conducted an exploratory analysis that included only female participants ( $n = 167$ ) and found that the results were identical to our full sample results.



al., 2015), our finding is first to illuminate PTS's inverse relation with *availability* of reward in one's environment. Consistent with previous research, access to reward was also negatively associated with alcohol use and alcohol-related problems (Correia, Benson, & Carey, 2005; Vuchinich & Tucker, 1988).

In partial support of our hypothesis, access to environmental reward mediated the relation between PTS symptoms and both alcohol craving and related-problems. Further, access to reward accounted for a moderate to large amount of the total effect. Craving is recognized as a core symptom of alcohol use disorder (American Psychiatric Association, 2013). Previous research has identified a connection between alcohol craving and reward dysfunction, specifically an increased attentional bias toward alcohol-related stimuli (Heinz et al., 2004; Wrase et al., 2007). Further, craving has previously been linked to negative affect and PTSD (Coffey, Gudleski, Saladin, & Brady, 2003; Soltis et al., 2017); however, no study has examined the mechanisms that account for the relation between PTSD and craving. Our study bridges the gap between these separate inquiries by suggesting that reward deprivation mediates the relation between PTS symptomatology and alcohol craving. These findings provide initial support the idea that diminished access to environmental reward plays a key role in understanding high levels of alcohol misuse among individuals with PTS symptoms.

Individuals struggling with PTS symptoms may live in environments that are devoid of natural rewards (e.g., impoverished urban or rural areas with few quality education, social, or recreational resources), avoid exposure to their environment due to the presence of trauma cues, or lack social and self-regulatory capabilities necessary for engaging in alternative reward, all of which result in diminished access to reward and increases in the relative value of alcohol as a reward. This overreliance on alcohol as a reward may lead to decision to drink in high risk situations, or decisions to drink in a manner that maximize subjective intoxication and experience of (immediate) reward. PTS-related avoidance may also diminish social support or other natural protective factors against alcohol-related problems that many college students have regularly available, thus increasing propensity for problems. Consistent with the reinforcer pathology model (Bickel et al., 2014), all of this may lead to patterns of drinking that are driven by strong urges and that are likely to result in negative consequences.

Contrary to our hypothesis, ability to experience reward did not mediate the relation between PTS and alcohol-related problems. This was somewhat surprising given that prior studies have found that PTSD was associated with blunted response to rewards (Elman et al., 2005). In our study, nonsignificant relations between ability to experience reward and PTS symptom severity may be related to characteristics of our sample and the unique nature of disordered reactions to trauma. The previously mentioned study used a behavioral task, excluded participants that did not meet diagnostic criteria for PTSD, and consisted of only males - all reasons for why our findings may not have been congruent. Neural reward function have been shown to be hypoactive in individuals with a PTSD diagnosis, and Sailer et al. (2008) found that PTSD patients showed blunted activation in two important structures important for reward processing, the nucleus accumbens and the medial prefrontal cortex. This attenuated functional activation of individuals with PTSD may be responsible for high levels of anhedonia and blunted reward response. However, it is unclear if this same neural

dysfunction is present in the current sample of less-severe college students, or if our self-report measure of reward experiences adequately captures the neural elements of reward (Treadway & Zald, 2011).

The bivariate association between PTS symptomatology and alcohol consumption was modest, and the nonsignificant mediations suggest that PTS symptomatology does not influence alcohol consumption through reward deprivation. Numerous previous studies suggest that negative mental health is more robustly related with increased problems associated with alcohol use rather than increased consumption (Pedrelli, Shapero, Archibald, & Dale, 2016). It may be that those with PTS symptoms avoid engaging with their college environment most of the time, thus diminishing the number of overall drinking occasions, but drink heavily while in a drinking scenario, increasing their propensity for experiencing problems.

### Strengths, Limitations, and Future Directions

The current study was one of only a few studies to examine comorbidity from a behavioral economic perspective and the first to evaluate the association between PTS, reward, and alcohol misuse. We examined two distinct domains of reward deprivation and three domains of alcohol misuse in a diverse urban college sample that experiences relatively high rates of trauma (Borsari et al., 2017; Tripp et al., 2015b), and our results extend behavioral economic models of alcohol misuse and comorbidity. Despite this, several limitations may limit the generalizability and interpretation of our findings which establish associations among these variables but cannot suggest directional causality. First, our sample was comprised primarily of female college undergraduates, who may present with PTS symptoms differentially from veterans or community populations. Although we lacked power to test gender interactions, the results held in analyses with only women, and future research will need to further explore these relations among men. Second, although our sample included significant variability in drinking and PTS symptom levels, not all participants were heavy drinkers, and the mean PCL symptom severity rating was below the cut-off. This study did not include a diagnostic assessment of PTSD, and although the RPI is reliable and valid, it does not precisely differentiate between substance-related and substance-free reward as is required to quantify the proportion of total reward related to alcohol and other drugs (Heinz et al., 2012). Third, directionality in our models cannot be assumed given the cross-sectional nature of our data and the relations are likely bidirectional. PTS may lead to a decrease in interaction with the environment, and thus a decrease in access to environmental reward, or college students with diminished access to environmental reward might be more susceptible to PTS exposure and subsequent symptomatology. It is also likely that increased levels of alcohol consumption and problems reduce reward availability and exacerbate PTS symptoms. Although we expect bi-directional relations and cannot establish directionality with our cross-sectional design<sup>3</sup>, our study provides preliminary support for the future study of these variables experimentally and longitudinally to further elucidate their reciprocal relation. Finally, other PTS symptom clusters, such as “negative alterations in cognition or

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<sup>3</sup>In fact, we tested models using alcohol misuse variables as the independent variables, PTS symptomatology as the dependent variable, and access to reward and ability to experience reward as the mediators. The results were nearly identical. Longitudinal design is necessary to elucidate the directionality of effects.

mood”, may result in a negative interpretation of drinking events or social interactions, which could lead to more endorsement or actual experience of problems. Future research should study these cognitions in conjunction with reward deprivation in order to identify unique variance explained by each symptom cluster.

### Clinical Implications

Although preliminary, our results may be relevant to efforts to prevent and treat symptoms of PTS among young adult drinkers. Prospective assessment of reward and activity patterns over time, in addition to standard assessment of PTSD and alcohol misuse, may help shed light on the comorbid relation between PTS and alcohol misuse. Our results suggest that interventions targeting comorbid alcohol misuse and PTS might benefit from a focus on increasing access to substance-free activities. Substance-related therapeutic techniques, such as contingency management, already address this issue, and recent applications of behavioral activation to the treatment of PTSD have been successful (Acierno et al., 2016; Gros et al., 2012). Additionally, behavioral economic brief intervention approaches have been developed to increase access to substance-free rewards, and one clinical trial found that this approach was especially effective for heavy drinking college students with symptoms of depression (Murphy et al., 2012).

### Summary

The current study found that reward deprivation is positively associated with both PTS symptoms and alcohol misuse and mediates the relation between PTS symptoms and alcohol craving and related problems. Although preliminary, our results provide initial support for behavioral economic reinforcer pathology models of PTS-alcohol misuse comorbidity. Future research should explore more precise and prospective measurement of trauma exposure, PTS, reward functioning, and alcohol misuse.

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**Public Significance Statement**

Our study is the first to examine reward deprivation (both access to and experience of reward) as a transdiagnostic risk factor for comorbid PTS-alcohol misuse. We found that lack of access to reward was associated with PTS symptomatology and mediates the relation between PTS and alcohol problems and craving. Future work should extend this research with experimental and longitudinal designs, and treatment for PTS-alcohol misuse comorbidity should address barriers to reward.

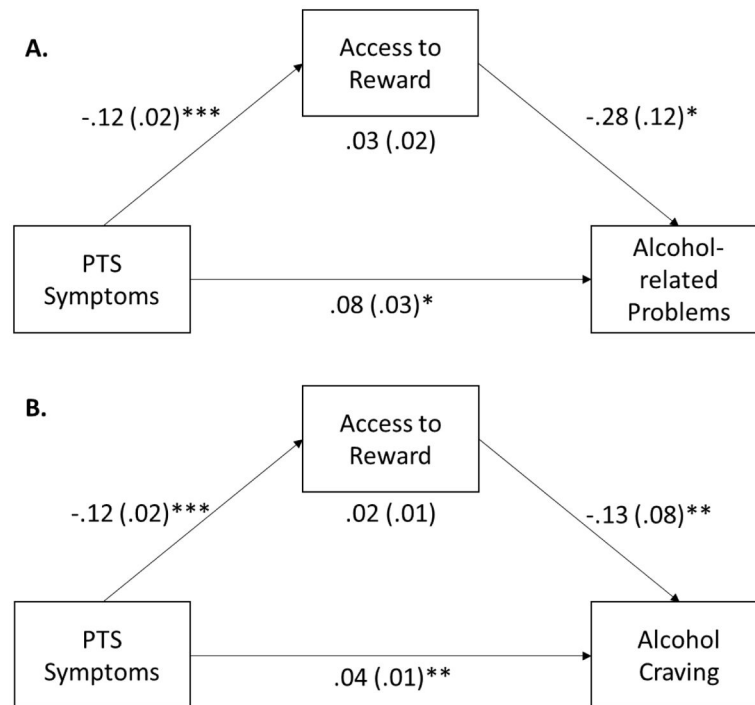
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**Figure 1.** Summary of the final significant single mediator models. Access to Environmental Reward Significantly mediates the relation between Post-traumatic Stress (PTS) Symptomatology and (A) Alcohol-related Problems and (B) Alcohol Craving. \*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$ .

Table 1

Means, Standard Deviations, and Correlations Among Study Variables

	<i>N</i>	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Gender				-						
2. Age	201	21.47	5.51	-.07	-					
3. Drinks per week	203	7.33	9.05	-.18*	.03	-				
4. Alcohol-related Problems	195	8.47	8.85	.01	-.02	.42***	-			
5. Craving	200	4.95	3.60	.01	.17*	.41***	.38***	-		
6. PCL-5 Score	203	22.29	18.34	.06	-.15*	.17*	.24**	.22**	-	
7. Reward Probability Factor	195	34.44	4.94	.00	-.02	-.15*	.00	-.22**	-.04	-
8. Access to Environmental Reward Factor	202	24.28	5.37	-.02	.20**	-.14*	-.25***	-.29***	-.43***	.19**

Note. PCL = PTSD Checklist for the DSM-5;

\*\*\*  
 $p < .001$ ,\*\*  
 $p < .01$ ,\*  
 $p < .05$

Summary of Single Mediators between PTSD symptoms and Alcohol Consumption, Craving, and Problems

Table 2

	<i>N</i>	Cov	<i>a</i>	<i>b</i>	<i>c</i>	<i>c'</i> (SE)	95% confidence interval
Alcohol Consumption <sup>‡</sup>							
Reward Probability	195	-	-.01	-.03	.01**	.00 (.001)	[-.001, .003]
Access to Reward	202	-	-.12***	-.02	.01*	.002 (.002)	[-.002, .007]
Alcohol Craving							
Reward Probability	192	1.10 (.22)***	.00	-.11*	.02*	.00 (.003)	[-.005, .005]
Access to Reward	199	1.07 (.21)***	-.12***	-.13**	.03**	.02 (.007)	<b>[-.005, .031]</b>
Alcohol-related Problems							
Reward Probability	188	3.31 (.52)***	.00	.10	.06	.00 (.003)	[-.01, .004]
Access to Reward	194	3.01 (.51)***	-.12***	-.28*	.08*	.03 (.02)	<b>[-.007, .07]</b>

Note. Controlling for Alcohol Consumption (where applicable). Cov = Beta weight (Standard Error) and significance level for alcohol consumption predicting the dependent variable in each equation controlling for other model variables; *a* = pathway from Independent Variable to Mediator; *b* = pathway from Mediator to Dependent Variable; *c'* = indirect effect of the Independent Variable on the Dependent Variable through the Mediator.

\*\*\* *p* < .001,

\*\* *p* < .01,

\* *p* < .05,

bold text indicates significant indirect effect.

<sup>‡</sup> Variable Transformed.