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Examining Cognitive Processes and Drinking Urge in PTSD

Jennifer P. Read^a, Rachel L. Bachrach^b, Jeffrey D. Wardell^c, and Scott F. Coffey^d

^aDepartment of Psychology, University at Buffalo, SUNY, USA

^bDepartment of Psychiatry, Western Psychiatric Institute and Clinic, USA

^cCampbell Family Mental Health Research Institute, Centre for Addiction and Mental Health, Toronto, Ontario, Canada

^dUniversity of Mississippi Medical Center, USA

Abstract

Despite their centrality to learning theories, strikingly little attention has been paid to the role of cognitions in efforts to understand associations between posttraumatic stress disorder (PTSD) and alcohol drinking. In the present study, we sought to examine information processing pathways for trauma and alcohol information, and the effects of posttraumatic stress and trauma cue exposure on these pathways. Participants were college students ($N = 232$; 49% female; $M_{age} = 19.56, SD = 1.44$) categorized into three diagnostic groups based on current PTSD status determined by structured clinical interview. These students then were exposed to a personalized trauma or neutral cue script, followed by a Stroop task modified to include trauma, alcohol, and contrast words. Indices of mood and urge to drink alcohol were administered throughout the task. Findings revealed that those with PTSD who were exposed to the personalized trauma cue showed a general response slowing across all stimuli types on the Stroop task. Intriguingly, this slowing effect was significantly associated with urge to drink alcohol for only those PTSD participants who were exposed to the trauma cues. In contrast, we did not find support for the hypothesis that trauma cues would lead to attention bias to trauma and alcohol specific Stroop stimuli among participants with PTSD, nor did slower RT for specific word types predict unique variance in urge to drink alcohol. Findings suggest that individual (PTSD) and environmental (cue) circumstances may work conjointly to precipitate changes in cognitive processing - changes that may have implications for drinking motivation. Given the importance of cognition in the etiology of both PTSD and drinking, this is a mechanism that warrants further investigation.

Keywords

PTSD; Cognition; Stroop; Trauma; Alcohol

Correspondence to: Jennifer P. Read.

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Appendix A. Supplementary data: Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.brat.2016.12.014>.

1. Introduction

Posttraumatic stress (PTSD) and problem drinking - including alcohol use disorders - frequently co-occur (e.g., Kaysen et al., 2014; Kline et al., 2014; Miller, Vogt, Mozley, Kaloupek, & Keane, 2006; Ouimette, Moos, & Finney, 2000; Read, Wardell, & Colder, 2013). Learning models such as self-medication often have been invoked to explain this association. Proponents of these models assert that drinking occurs as an effort to cope with trauma-associated negative affect. From this perspective, drinking can be understood as a learned response to internal or environmental affect-related cues (Bandura, 1986; Khantzian, 2003; Lang, Patrick, & Stritzke, 1999; Stasiewicz & Maisto, 1993; Stewart, 1996). Cognitions are a core component of many learning models (Maisto, Carey, & Bradizza, 1999; Moos, 2010), as it is through cognitive processes that individuals interpret internal and environmental stimuli and frame an appropriate course of behavioral responses. Yet despite their centrality to learning conceptualizations, strikingly little attention has been paid to the role of cognitive processes in PTSD-alcohol associations.

One way in which cognitions may be relevant to the link between PTSD and drinking is in how individuals with PTSD respond cognitively to reminders of their trauma, and how these responses may acutely influence drinking. One such cognitive response is the automatic biasing of attention, whereby when confronted with trauma cues, individuals with PTSD may focus attentional resources on trauma-relevant material, to the exclusion of other competing cognitive demands. Though the literature has been mixed (Kimble, Frueh, & Marks, 2009), several studies have demonstrated evidence of such attentional bias to trauma-relevant material. Specifically, using a modified version of the Stroop task (Stroop, 1935), where participants are asked to name the color in which different words are printed while ignoring the content of the words, at least some prior research has revealed slowed response times for naming the color of trauma-related words among those with PTSD (Amir, Coles, & Foa, 2002; El Khoury-Malhame et al., 2011; Kaspi, McNally, & Amir, 1995; McNally, Amir, & Lipke, 1996; Pineles, Shipherd, Mostoufi, Abramovitz, & Yovel, 2009). This word-specific slowing has been interpreted to be evidence of an automatic attention bias for word-types (i.e., trauma) that are associated with overly developed fear networks (Foa & Kozak, 1986; Kolassa et al., 2010; Litz & Keane, 1989). In the context of fear-relevant cues, cognitive resources are drawn toward that material, and away from the task of rapid responding to the colors.

Self-medication theory offers a framework for the potential relevance of such attentional bias for PTSD-alcohol pathways. For example, individuals with PTSD may exhibit not only a bias to attend to trauma-relevant words, but also to words associated with relief from trauma-related distress; that is, alcohol words. A cognitive bias for alcohol words has been linked to drinking risk (e.g., Cox, Blount, & Rozak, 2000; Johnsen, Laberg, Cox, Vaksdal, & Hugdahl, 1994; Stewart, Hall, Wilkie, & Birch, 2002), and the extent to which individuals with PTSD may exhibit such a bias – either with or without activation by a trauma cue - may be an important part of the risk pathway to problem drinking for these individuals.

There may be other ways in which cognitive responses to trauma cues serve to link PTSD and problematic drinking that go beyond just attentional bias. For example, the modified

Stroop has been used to assess not only attentional bias (e.g., Buckley, Blanchard, & Neill, 2000; Cox, Fadardi, & Pothos, 2006; Waters et al., 2003), but also executive functioning and self-regulatory capacities (Bugg, 2012; DeWall, Baumeister, & Vohs, 2008; Gonzalez, Fuentes, Carranza, & Estevez, 2001; Lurquin, McFadden, & Harbke, 2014). In these studies, slowed response time to name the color of Stroop stimuli is viewed as evidence of a depletion of executive and self-regulation resources, and as such, as a marker of vulnerability for problem behavioral outcomes. Deficits in self-regulation have been noted in those with PTSD, both acutely (Ford, 2013; New et al., 2009) and over time (Cloitre, Koenen, Cohen, & Han, 2002; Marx, Heidt, & Gold, 2005). Such deficits have been shown to be related to risk for problem substance misuse when studied at the static, trait-level (e.g., Miller et al., 2006; Read, Merrill, Griffin, Bachrach, & Khan, 2014), but have not been examined dynamically, in response to trauma stimuli. This is an important gap in the literature, as acute depletion of cognitive resources may render the individual with PTSD vulnerable to alcohol misuse. That is, absent more adaptive ways of managing when a person with posttraumatic stress is confronted with a reminder of his/her trauma, cognitive resources may be dynamically reallocated from task performance to urge-related responding. This resource depletion might be reflected in a general deficit in color-naming ability on the Stroop task following trauma-cue exposure that is not specific to the content of the Stroop words.

In summary, evidence from trauma and alcohol literature points to two ways in which cognitive processes may be part of a self-medication pathway between PTSD and drinking risk: (1) a specific attentional bias to threat and alcohol stimuli, and/or (2) via a more general suppression of self-regulatory capacity, that is not stimuli specific. Either or both of these processes could be critical to drinking risk for those with PTSD and as such, could be a target for preventive and treatment interventions. Yet, no study to our knowledge has looked at how information processing in those with posttraumatic stress may be proximally related to motivation to consume alcohol (e.g., urge to drink). Such questions have both conceptual and practical relevance, as the answers could shed light on the nature of the association between PTSD and alcohol use, pointing to directions for interventions, particularly with regard to in-the-moment drinking situations.

Accordingly, in the present study, we sought to examine potential cognitive pathways for trauma and alcohol information, and the effects of posttraumatic stress and trauma cue exposure on these pathways. We were interested in testing both the specific (attentional bias to particular word types) and more general (nonspecific slowing following trauma cue) dimensions of these processes as a potential link between PTSD and drinking risk. We examined urge to drink as an indicator of such risk. We expected that we would observe slower color-naming responses on a Stroop task for participants with PTSD (relative to those without PTSD), but only under conditions where those participants had been exposed to a personally-relevant trauma cue. Further, we expected that color-naming response times would be especially slow for trauma and alcohol related words, reflecting an attentional bias toward those motivationally relevant stimuli as a function of self-medication processes. Finally, because we were interested in the link between these cognitive processes and in-the-moment drinking risk, we examined how these response time patterns were related to urge to

drink alcohol, and how cue context and PTSD symptomatology moderated these associations.

2. Method

2.1. Participants

Participants for the present study were undergraduate students ($N = 232$; 49% female; $M_{\text{age}} = 19.56$, $SD = 1.44$) recruited from public and private universities in western New York. Eligible participants were between the ages of 18-24, native English speakers, enrolled full time at a 4-year university, and drank alcohol at least once per month in the three months prior to participation in the study. In addition, individuals were not eligible if they reported significant hearing impairment or color blindness. Students were recruited and identified for initial eligibility through the university's psychology research pool (i.e., students taking introductory psychology) or through advertisements in the community (e.g., flyers, newspaper ads, Craigslist, etc). Thirty-nine percent of participants were freshman ($n = 90$), 21% were sophomores ($n = 48$), 20% were juniors ($n = 47$), 18% were seniors ($n = 42$), and 5 students reported another education status. Approximately half of the participants (53%) lived on campus, with some living off campus (32%) or at home with family (15%). Race was reported as follows: 74% Caucasian, 12% African American, 9% Asian, 2% Multiracial, and 3% Other. Of these, 6% identified with Hispanic ethnicity. The average reported GPA was 3.01 ($SD = 0.55$) on a 4-point scale. This represents a "B" average. In the past 90 day period, participants reported drinking a total of 112.90 ($SD = 111.88$) standard drinks on average over a mean of 16.56 ($SD = 12.63$) drinking days. This represents an average of 6.24 ($SD = 3.06$) standard drinks per drinking day and an average of 11.16 ($SD = 10.28$) heavy drinking episodes over the 90 day period (defined as 4+/5 + drinks for women/men).

2.2. Screening and assessment procedure

All procedures were approved by the university's Institutional Review Board.

2.2.1. Screening procedures—Participants recruited through Introductory Psychology courses ($n = 154$) were recruited through a mass testing procedure, in which initial eligibility criteria were assessed. Students recruited via the community ($n = 78$) were screened by telephone for initial eligibility. Based on responses to this initial screen (which included age, native language, student-status, past 3-month alcohol consumption, hearing impairment, and color blindness), participants were invited for an in-person assessment session to further confirm eligibility.

2.2.2. Assessment session procedures—During the assessment session, participants were interviewed using the Life Events Checklist (LEC; Gray, Litz, Hsu, & Lombardo, 2004; see *Measures*) and the Clinician Administered Post-Traumatic Stress Disorder Scale for DSM-IV (CAPS; Blake et al., 1995; see *Measures*) to assess for a Criterion A traumatic event and posttraumatic stress symptoms. All interviews were conducted by trained, doctoral-level graduate students in clinical psychology. Consistent with procedures outlined by Coffey et al. (2002), material for the trauma cue condition was generated from the guided imagery interview conducted during the assessment session (see description of cue scripts,

below). Based on the CAPS interview, three groups of eligible participants were identified and invited to participate in the second portion of the study (see *Experimental Session*): (1) participants with no history of Criterion A trauma exposure and who reported minimal or no PTSD symptomatology (i.e., no B symptoms, 1 C symptom, and/or 1 D symptom; “Trauma Negative”); (2) individuals with DSM-IV defined Criterion A exposure and who reported minimal or no PTSD symptomatology (i.e., no B symptoms, 1 C symptom, and/or 1 D symptom; “PTSD-Negative”); and (3) individuals meeting current (past month) full PTSD criteria (i.e., 1 B symptom, 3 C symptoms, and 2 D symptoms; “PTSD-Positive”). Those in the PTSD Negative (PTSD-) group also never met for lifetime PTSD. The assessment session lasted approximately 2 h and all students were given the choice of either course credit or \$20 cash for study compensation.

Of 406 participants who were identified during screening as likely eligible, 308 were found to have significant PTSD symptoms, and invited to the experimental session. Of these, 285 came back for the experiment and had usable data on the Stroop task. Because we expected cue and urge effects to be strongest in those with full PTSD symptom presentations, participants ($n = 53$) whose PTSD symptoms fell below DSM (APA, 2000) diagnostic threshold were excluded from further analyses. This resulted in a final N of 232.

2.3. Experimental session procedures

Eligible participants were invited to participate in the experimental portion of the study. Average length of time between sessions was 10.81 days ($SD = 6.74$ days). Experimental sessions were conducted between 11:00 a.m. and 5:00 p.m. Prior to arrival, eligible participants were randomly assigned (within sex and PTSD condition) to a Trauma Cue or Neutral Cue condition. Within each PTSD category, roughly equal numbers of participants were assigned to each cue condition, $\chi^2(2) = 0.65$, $p = 0.722$. See Table 1 for breakdown of trauma versus neutral cue assignment across the three PTSD groups.

Following consent procedures, participants were led into the experimental room, which held a desk, two chairs, and a computer. They were first asked to complete a baseline evaluation of state affect (Affect Grid; Russell, Weiss, & Mendelsohn, 1989) and an alcohol urge questionnaire (see *Measures*). Before completing these measures, participants were given a glass of water to control for thirst level.

Next, participants were introduced to the experimental task, which included 5 blocks of Stroop stimuli. Prior to completing each block, participants listened to an audio-taped script (personalized trauma cue or neutral cue, based on random assignment) over headphones. Participants then wrote for 2 min about what they had heard (see below). Next, participants rated their state affect, and were then instructed to complete the first of five blocks of the Stroop task (see *Measures*). This procedure was repeated (i.e., script, rating affect, and completing a block of the Stroop stimuli) until the five blocks of the Stroop task were complete. At the end of the entire task, we assessed participants' urge to drink alcohol. Finally, participants completed an assessment of their typical drinking using a past 90-day Timeline Follow-Back Interview (Sobell & Sobell, 1992; see *Measures*), and were debriefed. The Experimental Session took approximately 2.5 h to complete and students were given the

option of receiving either \$30 or credit towards the experiment component of their psychology course as compensation.

2.4. Assessment session: materials and measures

2.4.1. Demographic characteristics—A range of demographic factors (e.g., gender, age, ethnicity, residential status, school year) were assessed.

2.4.2. Life Events Checklist—The Life Events Checklist (LEC), is a measure of traumatic life events developed to be used in conjunction with the Clinician Administered PTSD Scale (CAPS). This measure is comprised of a list of 16 potentially traumatic events known to be associated with the development of posttraumatic stress. Participants are presented with this list, and check all that have happened to them. An interviewer then follows up each checked item to determine whether that event is consistent with a trauma as defined by the DSM. These events then become the basis of the PTSD structured interview assessment (CAPS; see below). The LEC has been widely used to assess traumatic events consistent with the DSM, and has been validated for use in college samples (Gray et al., 2004).

2.4.3. Post-traumatic stress disorder interview—Participants were assessed for PTSD status with the CAPS (Blake et al., 1995), an interview used to assess trauma exposure (Criterion A) and related PTSD symptoms. All symptoms were linked to participants' three most distressing Criterion A traumatic events, based on the LEC (Gray et al., 2004). Past month symptoms were assessed to determine current PTSD status. The CAPS has excellent psychometric properties (Blake et al., 1995), including concurrent validity with the Structured Clinical Interview for the DSM-IV (First & Gibbon, 2004). All interviews were digitally audio-recorded and agreement on PTSD status (inter-rater reliability) was conducted both between interviewers and by the fourth author. Approximately 25% of interviews were reviewed for inter-rater reliability ($Kappa = 0.88$).

2.5. Experimental session: materials and measures

2.5.1. Modified-Stroop Task—The effects of the cues on information processing were assessed using a modified Stroop color-naming task. Stimuli were presented using DMDX software (Forster & Forster, 2003) on a desktop computer, and words appeared on a monitor in red, blue, green, or yellow font color. Participants were instructed to name the color of a target word as quickly and as accurately as possible while ignoring the meaning of the word itself. A microphone attached to the headset was calibrated for each participant and recorded the responses and response times (i.e., time from stimulus onset to onset of vocal response). Participants began the task with 10 practice color-naming trials before completing 5 blocks of target stimuli.

Stimuli for this task consisted of 5 different word types grouped into separate blocks based on semantic content: trauma words, alcohol words, failure (negative) words, non-alcoholic beverage words, and furniture (neutral) words. Words were selected based on pilot work, in which trauma-exposed student participants ($N = 48$) rated a list of high-frequency trauma

words (e.g., ambulance, threaten, etc.) on arousal, valence, and relevance to the category (trauma, furniture, etc. Read & Coffey, 2009).

Each block of words was introduced, reminding participants to name the ink color as quickly and accurately as possible. Stimuli were presented individually on a gray background, in random order within each block. Each block contained words from the same category (e.g., trauma) and the order of the 5 blocks was randomized across participants. The color of the stimuli was balanced within each block, but each word always appeared in the same color for all participants (i.e., “vodka” was always green). Each stimulus was presented for a fixed interval of 500 ms and the participants had 1500 ms to respond from the time of stimulus onset before the trial timed out. Inter-trial intervals varied between 1000 and 2000 ms.

2.5.2. Affect Grid—The Affect Grid (Russell et al., 1989) was used to assess pre and post-manipulation mood state during the Stroop task. Participants marked an “X” on a 2×2 grid to report their current mood along valence and arousal dimensions. Each dimension is rated on a 9-point scale with higher values indicating greater endorsement of that affective dimension. “High Arousal” and “Sleepiness” anchor the two ends of the arousal dimension of the grid, and “Pleasant” to “Unpleasant” anchor the valence dimension. This measure has been used in mood manipulation studies (see Russell et al., 1989) and with college students (Killgore, 1998, 1999). Participants rated their mood after each of the 5 cue presentations and again at the end of the experiment.

2.5.3. Alcohol urge—Consistent with other studies of urge to use substances (e.g., Rohsenow, Monti, Abrams, & Rubonis, 1992; Sayette & Hufford, 1997), urge to drink alcohol was assessed with the question, “To what extent do you feel an urge to drink an *alcoholic beverage* right now?” Participants rated urge intensity on a 10-point Likert scale ranging from “*no urge to drink at all*” to “*very strong urge to drink*.” Urge was assessed before and after the cue exposure and Stroop task.

2.5.4. Drinking behavior—Past 3-month alcohol use was assessed with the Timeline Follow-Back (TLFB; Sobell & Sobell, 1992), a calendar-assisted interview that provides a way to cue memory to enhance accurate recall. The TLFB has excellent reliability and validity (Sobell, Sobell, Leo, & Cancilla, 1988). Interviews were conducted by bachelors-level research assistants trained by the first author. Total 90-day alcohol quantity was used in the analyses.

2.5.5. Trauma and neutral cue scripts—As stated above, the personalized trauma cue was derived from the participants’ own Criterion A traumatic event. For those individuals (i.e., the Trauma-group) who reported no lifetime Criterion A trauma, the assessment interview included a query regarding the most stressful or distressing event that has ever happened to him or her based on the events that the participant endorsed on the LEC, or another stressful event if none of the items on the LEC were endorsed. For those individuals in the PTSD positive (PTSD+) or negative (PTSD-) groups who reported multiple events that met Criterion A, participants were asked to describe their “worst or most upsetting” traumatic event. In all cases, participants were guided by the interviewer to describe the selected event in as much detail as possible. This required participants to detail actions,

thoughts, physical sensations, emotions, and sensory information experienced during the event. These guided imagery interviews were transcribed into a narrative which was audio-recorded by either a male or female research assistant (matched to participant gender) between the Assessment and Experimental session.

Participants who were subsequently assigned to the neutral cue condition did not listen to this script during the experiment but instead listened to a recording of a detailed, first person account of a neutral event (i.e., washing one's face and brushing one's teeth) that also included actions, cognitions, emotions, physiological sensations, and sensory components. All cues were presented for 120 s (2 min) so that exposure was standardized across participants.

Participants listened to the audio cues over headphones, with their eyes closed, and were asked to imagine what was being described as vividly as possible. To ensure participants were fully attentive and immersed in the cue exposure, they were asked to write about the script for 2 min after each cue presentation.

3. Data analytic approach

3.1. Data cleaning and descriptives

Vocal responses to Stroop stimuli were reviewed for accuracy using CheckVocal software (Protopapas, 2007). Trials were set to missing if the participant gave no response (2.4%), made an error (1.1%), or the RT was less than 200 ms. RTs that were influenced by a nonverbal event (e.g., breathing, background noise) were manually adjusted using CheckVocal (25% of trials) and the adjusted RTs were used in the analyses. The RTs closely approximated normal distributions, and no univariate outliers were observed. Further, the residuals from the regression analysis satisfied the normality assumption.

Next, t-tests and ANOVAs were conducted to examine associations of cue condition and PTSD status with self-reported alcohol use and PTSD symptoms, as well as affect and urge to drink ratings during the experimental session. Also, post-cue mood ratings (repeated assessments following each of the five cue exposures) were examined across cue conditions to provide a manipulation check for the trauma cue exposure.

3.2. Effects of cues and PTSD status on stroop RTs

To account for the clustering of RTs due to stimuli specific characteristics such as word length and word frequency (Judd, Westfall, & Kenny, 2012; Wardell & Read, 2013), as well as order effects (i.e., practice and fatigue effects) nested within participants, we used multilevel modeling (MLM; SPSS v. 20 MIXED function; IBM Corp, 2011) to test our primary aims. RTs to each Stroop stimulus were specified as the outcome, and participants contributed up to 100 observations to the analysis, resulting in a total of 23,200 possible observations. After removal of observations with missing RTs or mood covariates, there were 22,275 valid observations for analysis (3.66% missing).

Fixed effects were specified at level 2 (i.e., between-person) for cue condition (0 = neutral, 1 = trauma) and PTSD status (contrast coded to compare PTSD + vs. the PTSD- and Trauma-

groups combined, and PTSD-vs. Trauma-). Level 1 (i.e., within-person) fixed effects were specified for word type (4 dummy coded variables with furniture words as the referent group) and block order (a grand mean centered linear effect). Post-cue valence and arousal ratings (person mean-centered) were level 1 covariates, person-level mean valence and arousal ratings across the 5 cue exposures (grand mean centered) were level 2 covariates. All 3-way (word type, PTSD status, cue) interactions were modeled, as were all 2-way interactions.

To determine the appropriate random covariance structure, we first specified random intercepts for participant and for stimuli. We next entered the random slopes for the dummy coded word type effects, and conducted a likelihood ratio test to determine whether this improved model fit. We next examined whether the addition of random slopes for the level 1 covariates (block position, post-cue valence and arousal ratings) also improved model fit.

To determine whether the effects of cues and PTSD on RTs were specific to trauma- and alcohol-related words, we first examined the 3-way interactions between word type, cue condition, and PTSD status. We planned to probe significant interactions using simple slopes analysis (Aiken & West, 1991). If no significant 3-way interactions were observed, we planned to test the alternative hypothesis that trauma cues may lead to a general depletion of cognitive resources for individuals with PTSD. To do so, we planned to trim non-significant 3-way interactions from the model and examine the interaction of cue condition with PTSD status on RTs in general (i.e., not conditioned on word type).

3.3. Effects of stroop RTs on urge to drink alcohol

We also examined whether cue-related slowing on the Stroop task predicted end-of task urge to drink alcohol, and whether PTSD status moderated this association, using regression analyses. Standardized scores for baseline urge to drink, past 90 day alcohol quantity, and end-of-task mood ratings (valence and arousal) were entered as covariates. Consistent with our analysis of the effects of cues and PTSD status on RTs, we planned to examine both overall Stroop RTs and RTs to specific word types as a predictor of urge to drink. Dummy coded cue condition and contrast-coded PTSD status variables were entered as predictors, along with all 3-way interactions with Stroop RTs to examine their moderating effects.

4. Results

4.1. Descriptive statistics

Table 1 describes demographic and study-related variables by cue condition and PTSD status. As expected, PTSD positive (PTSD+) participants reported greater total alcohol consumption over the past 90 days than PTSD- and Criterion A negative (Trauma-) participants. PTSD status also was related to baseline urge to drink. Further, PTSD + participants endorsed the greatest number of traumatic events on the Life Events Checklist, followed by PTSD-participants and then by Trauma-participants (see Table 1).

The events described as “most distressing” by participants during the trauma/PTSD assessment (and thus that served as the basis of the trauma scripts for those in the trauma cue condition) varied only somewhat across the groups. For PTSD + participants, these were

sexual assault ($n = 8$; 29%), sudden unexpected death of someone close ($n = 6$; 21%) and transportation accident ($n = 4$; 14%). For PTSD-participants, the top three events were transportation accident ($n = 27$; 24%), life threatening illness or injury ($n = 20$; 18%), and sudden violent death of a loved one ($n = 13$; 12%). Finally, for Trauma-participants, the events most frequently chosen as the most distressing were sudden, unexpected death of someone close ($n = 21$; 23%), transportation accident ($n = 14$; 15%), and life threatening illness or injury ($n = 14$; 15%).

The results of the manipulation check indicated that the cue exposure had the intended effects on mood. There was a main effect of cue condition such that participants in the trauma condition reported feeling less pleasant and more aroused overall (Table 1). There was also a significant Time X Cue Condition interaction for both valence and arousal ratings ($ps < 0.05$). Follow-up simple effects tests showed a linear decline in pleasantness ratings for participants in the neutral condition ($p < 0.001$), whereas participants in the trauma condition maintained low pleasantness ratings across exposures ($p = 0.123$). Conversely, arousal ratings were low and steady in the neutral condition ($p = 0.161$), but started out high and showed a linear decline with each repeated cue exposure in the trauma condition ($p < 0.001$).

Moreover, PTSD status had a main effect on valence and arousal ratings following each cue exposure, with the PTSD positive group showing lower pleasantness rating and greater arousal ratings on average across the 5 repeated cue exposures (see Table 1). However, there were no significant 3-way interactions among PTSD status, cue condition, and time for either the valence or arousal ratings ($ps > 0.10$), nor were the 2-way interactions between PTSD status and time or between PTSD status and cue condition statistically significant ($ps > 0.10$). Valence and arousal ratings at each time point broken down by cue condition and PTSD status are available in Supplemental Table 1.

4.2. Effects of cues and PTSD status on stroop RTs

Mean RT to each word type by cue condition and PTSD status are available in Supplemental Table 2. In specifying our MLM of the effects of cue and PTSD status on Stroop RTs, the results of the likelihood ratio tests indicated that inclusion of random slopes for word type improved the fit of the model, $\chi^2(4) = 834.07$, $Dc p < 0.001$. Estimating a random slope for block position led to further model fit improvement, $\chi^2(1) = 128.44$, $p < 0.001$. However, estimating a random slope for post-cue arousal ratings did not improve model fit, $\chi^2(1) = 0.76$, $p = 0.38$. We encountered estimation problems when attempting to include a random slope for post-cue valence ratings, possibly due to the relatively low within-person variance in this variable ($ICC = 0.80$). Thus, the mood covariates were modeled as fixed effects only. Finally, including the covariance estimates among the random intercept and random slopes for word type and block position improved model fit, $\chi^2(15) = 88.14$, $p < 0.001$, and so an unstructured covariance Dc matrix was specified in the final model.

In examining the fixed effects for the 3-way interactions between word type, cue condition, and PTSD status, we found no statistically significant interactions involving word type (all $ps > 0.36$). Thus, we removed these word type interactions in order to examine the effects of cue condition and PTSD status on Stroop RTs overall (Table 2).

Examination of the fixed effects revealed a significant interaction between cue condition and the contrast-coded variable comparing PTSD + participants to PTSD- and Trauma-participants (See Fig. 1). The interaction between cue condition and the contrast comparing PTSD-vs. Trauma-groups was not significant. Simple slopes analyses revealed that PTSD + participants in the trauma condition had slower overall RTs relative to PTSD + participants in the neutral condition ($B = 89.23$, $SE = 39.45$, $p = .025$). RT differences across the trauma and neutral cue conditions for PTSD- and Trauma - participants were not significant ($ps > 0.46$).

4.3. Effects of stroop RTs on urge to drink alcohol

We first examined the results of the regression model with RTs to each of the 5 different word types modeled separately. In this model, none of the interactions between RTs to the specific word types, cue condition, and PTSD status were significant (all $ps > 0.05$).

We next examined the regression model predicting post-cue urges to drink alcohol from overall average RTs on the Stroop. We found a significant 3-way interaction between RTs, cue condition, and the PTSD + versus PTSD- and Trauma-comparison (Table 3). The 3-way interaction involving the PTSD-vs Trauma-contrast was not significant. Simple slopes analysis revealed that cue condition moderated the association between RTs and urge to drink alcohol for PTSD + participants (interaction $B = 1.38$, $SE = 0.55$, $p = .01$) but not for PTSD- (interaction $B = 0.13$, $SE = 0.35$, $p = .71$) or Trauma-participants (interaction $B = -0.11$, $SE = 0.45$, $p = .80$). Further probing revealed a significant positive association between RTs and urge to drink alcohol for PTSD + participants exposed to the trauma cue ($B = 0.98$, $SE = 0.39$, $p = .01$) but not for PTSD + participants exposed to the neutral cue ($B = -0.38$, $SE = 0.38$, $p = .31$). Thus, the general Stroop slowing was associated with greater post-cue urge to drink alcohol, but only for individuals with PTSD, exposed to a trauma cue. Also, the mood and alcohol use covariates were not associated with urge (see Table 3). See Fig. 2 for plots of the simple slopes.

5. Discussion

In this study, we sought to examine some of the automatic cognitive processes that may link PTSD to drinking, namely, biased attention to trauma and alcohol stimuli and the depletion of cognitive resources in response to trauma cues. We found that individuals with PTSD who were exposed to a personalized trauma cue showed broad slowing of task performance, across all stimuli types, suggesting interference with information processing. Intriguingly, this slowing effect was significantly associated with urge to drink alcohol. In contrast, we did not find support for the hypothesis that trauma cues would lead to attention bias to trauma and alcohol specific Stroop stimuli among participants with PTSD, nor did slower RT for specific word types predict unique variance in urge to drink alcohol. We discuss these findings and their implications in greater detail below.

In our study, PTSD status exerted an influence on information processing capacity, but only in the context of a trauma cue. That is, participants with PTSD and who were exposed to their own personalized trauma cue were generally slower to respond to Stroop stimuli. Further, this overall slowing to Stroop stimuli predicted in-the-moment urge to drink alcohol

for these same participants; those with PTSD who listened to a neutral script did not show the same relationship between RTs on the Stroop task and urge to drink. This suggests the potential for a specific vulnerability for drinking among those with PTSD that appears to be related to trauma cue influences on cognitive processes. Importantly, we observed this effect over and above the variance that was accounted for by mood differences across the groups.

What might explain this pattern of slower response times on the Stroop task and its association with urge to drink? One possible interpretation of the present findings is that trauma cues result in a general depletion of cognitive resources among individuals with PTSD, which is acutely linked to motivation (urge) to consume alcohol. Though in both the PTSD and alcohol literature, the Stroop has been used as an index of attentional bias (e.g., Cox et al., 2006; Waters et al., 2003), the broader literature has highlighted patterns of Stroop responding as being reflective of executive functioning and self-regulatory capacities (Bugg, 2012; Gonzalez et al., 2001) which, when compromised, may pose risk for alcohol use or misuse. As such, the pattern of response slowing that we observed in this study could be interpreted through the lens of the resource-depletion framework described by Litz and Keane (1989). Specifically, when those with PTSD are confronted with traumatic stimuli, preoccupation with this information may cause cognitive resources to be drawn away from concurrent demands, such as task responding. This general slowing of RTs, an index of cognitive resource depletion, in the context of alcohol urge is consistent with Sayette et al. (1994) who found slower RTs to auditory tones among alcohol dependent participants when exposed to alcohol cues. Moreover, RT was significantly correlated with self-reported urge to drink. As executive functioning may regulate behavioral urges, our results provides encouraging preliminary evidence that contextual factors such as trauma cues may diminish self-regulatory resources (through depletion of cognitive resources), leading to a cascade of processes that may influence drinking behavior further downstream.

Notably, the slower RTs on the Stroop task that we observed among PTSD positive participants in the trauma cue condition was not specific to trauma or alcohol words. Such specific slowing would have been consistent with attentional bias theories of cognitive processing in PTSD, whereby individuals with PTSD may automatically orient attention toward trauma-specific words, impacting color naming RTs specifically for those stimuli. Some prior literature has offered evidence of such an attentional bias (El Khoury-Malhame et al., 2011; Foa, Feske, Murdock, Kozak, & McCarthy, 1991; Kaspi et al., 1995; Krans, Reinecke, de Jong, Naring, & Becker, 2012; McNally et al., 1996; Pineles et al., 2009). However, only one of these studies conducted tests of PTSD-related interference effects in the context of a trauma cue (Krans et al., 2012), and this study found only modest support for an attentional bias toward trauma-specific words. Thus, it may be that when a salient cue is present (e.g., a personalized description of a traumatic event), cognitive resource depletion is a more dominant process than attentional bias.

Moreover, work by Kimble et al. (2009) suggests that findings regarding PTSD and attentional bias may be more mixed than the extant literature depicts. Specifically, in a review that included both peer-reviewed articles and dissertation abstracts, Kimble et al. concluded that a combination of “file drawer” and “top drawer” publication biases may have overstated the reliability of PTSD effects on attention bias toward trauma-related stimuli.

The present study offers a strong test of both attentional bias and interference in the contexts of personalized trauma cues. Our findings help to shed light on a complex literature, delineating distinct cognitive processes that may be relevant in this context.

5.1. Limitations and future directions

This study had limitations that should be considered in the interpretation of our findings. First, we were interested in examining the unique and combined effects of PTSD and trauma cue exposure on cognitive processes. Though we experimentally manipulated trauma cue condition, allowing us to isolate the specific effects of these idiosyncratic cues, the PTSD variable was, of course, not subject to experimental manipulation. As such, we are not able to rule out third-variable explanations for some of the PTSD effects that we observed.

Consistent with other studies of urge to use substances (e.g., Cooney et al., 2007; Sayette & Hufford, 1997), intensity of urge to drink alcohol was evaluated using a single, Likert-type item. Though single item assessments have been shown to detect desire to use alcohol in laboratory and other settings and indeed to correlate with actual use (e.g., Cooney, Cooney, Pilkey, Kranzler, & Oncken, 2003; Monti, Rohsenow, & Hutchison, 2000; Vinci et al., 2014; Wardell, Ramchandani, & Hendershot, 2015), single item assessment of any construct is vulnerable to unreliability.

Further, though the trauma cues were generated by participants themselves, the neutral cues were provided by investigators. This methodology was guided by our own past experiences with the development of neutral cues, and was designed to maximize the likelihood that neutral cues would be free of emotional content. Still, it is possible that the personal relevance of the trauma cues -rather than the traumatic content *per se* - contributed to the participant responses that we observed. Further, though participants may have experienced multiple traumas, we used the one that was identified as the most distressing of the three to serve as the trauma cue. Thus, it is possible that some of the PTSD symptoms reported by participants were not linked specifically to the single trauma represented in the trauma cue. This could have diluted the impact of the trauma cue.

In addition, although we found PTSD and trauma cues to be associated with urges to drink, the mediated pathway from cues to actual drinking behavior through cognitive interference was not tested. Our interpretation of the slowing that we observed for those with PTSD in the trauma cue condition is that it reflects a taxing of executive resources that may be relevant to acute desires to consume alcohol. This is consistent with a large literature that has linked slowed responding on the modified Stroop Task to a depletion of cognitive resources that are relevant to self-control, and thus, to substance use behavior (e.g. Baumeister, Vohs, & Tice, 2007; Cranwell et al., 2014; Hagger et al., 2013). Additional studies that test the fully mediated pathway to in vivo drinking behavior are needed for a clearer delineation of the cognitive processes that may undergird drinking.

Finally, there were features of our sample that may qualify conclusions about to whom these findings may generalize. For example, ours was not a clinical or a treatment-seeking sample. The effects observed here might be different in such samples, as those with more severe or long-standing PTSD or alcohol involvement may be more likely to show evidence

attentional bias for alcohol and trauma specific words. As such, tests of the questions posed here with clinical samples will be an important next direction for this work. It may also be useful to use within-subjects designs that can avoid potential confounds such as between-person differences in trauma-types across cue conditions. Related to this is that the primary objective of our study was to examine specific and theorized processes in the PTSD-alcohol use relationship. As such, we did not assess other types of psychopathology that may also play a role in drinking. Given that PTSD commonly presents with other psychological disorders, an interesting question for future research is to what extent the processes that we observed are specific to PTSD versus shared by other instantiations of negative affect. This sample also was comprised of young, predominantly white, college students. Though ample evidence suggests that PTSD occurs in college samples and is associated with drinking (e.g., Kaysen et al., 2014; Read, Ouimette, White, Colder & Farrow, 2011) it remains to be seen whether the present findings reflect similar processes for other groups. Finally, it will be interesting to determine in future work whether the associations observed here generalize to other substances such as marijuana or nicotine, both of which also have been shown to co-occur commonly with PTSD.

6. Conclusions and implications

This study provided a novel examination of cognitive processes that may be linked with alcohol use among individuals with PTSD exposed to a trauma cue. Findings suggest that individual (PTSD) and environmental (cue) circumstances may work conjointly to precipitate changes in cognitive processing – changes that may have implications for drinking motivation. As such, our findings offer preliminary support for a cognitive pathway by which PTSD and trauma cues might influence drinking behavior. Given the centrality of cognition in the etiology of both PTSD and drinking, this is a mechanism that warrants further investigation.

The delineation of cognitive pathways that may link PTSD and drinking risk may have some important clinical implications for those being treated for co-occurring PTSD and alcohol use disorder. For example, several studies have examined self-regulation as a target for intervention for those in psychological distress, and have offered evidence that cognitive capacity for self-regulation can be altered through intervention (Houben et al., 2011; Palfai, 2004, 2006). Such approaches may be beneficial for individuals with PTSD who also drink problematically. Continued study of these cognitive processes may point to the development or refinement of interventions that may target self-regulation risk for using alcohol in response to trauma exposure and PTSD symptoms.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

- Aiken, L.S., West, S.G. Multiple regression: Testing and interpreting interactions. Thousand Oaks, CA: Sage Publications; 1991.
- Amir N, Coles ME, Foa EB. Automatic and strategic activation and inhibition of threat-relevant information in posttraumatic stress disorder. *Cognitive Therapy and Research*. 2002; 26:645–655.
- American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th. Washington, DC: 2000. Text Revision
- Bandura, A. Social foundations of thought and action: A social cognitive theory. Upper Saddle River, NJ: Prentice Hall; 1986.
- Baumeister RF, Vohs KD, Tice DM. The strength model of self-control. *Current Directions in Psychological Science*. 2007; 16:351–355.
- Blake DD, Weathers FW, Nagy LM, Kaloupek DG, Gusman FD, Charney DS, et al. The development of a clinician-administered PTSD scale. *Journal of Traumatic Stress*. 1995; 8:75–90. [PubMed: 7712061]
- Buckley TC, Blanchard EB, Neill WT. Information processing and PTSD: A review of the empirical literature. *Clinical Psychology Review*. 2000; 20:1041–1065. [PubMed: 11098399]
- Bugg JM. Dissociating levels of cognitive control: The case of Stroop interference. *Current Directions in Psychological Science*. 2012; 21:302–309.
- Cloitre M, Koenen KC, Cohen LR, Han H. Skills training in affective and interpersonal regulation followed by exposure: A phase-based treatment for PTSD related to childhood abuse. *Journal of Consulting and Clinical Psychology*. 2002; 70:1067–10723. [PubMed: 12362957]
- Coffey SF, Saladin ME, Drobos DJ, Brady KT, Dansky BS, Kilpatrick DG. Trauma and substance cue reactivity in individuals with comorbid posttraumatic stress disorder and cocaine or alcohol dependence. *Drug and Alcohol Dependence*. 2002; 65:115–127. [PubMed: 11772473]
- Cooney JL, Cooney NL, Pilkey DT, Kranzler HR, Oncken CA. Effects of nicotine deprivation on urges to drink and smoke in alcoholic smokers. *Addiction*. 2003; 98:913–921. [PubMed: 12814497]
- Cooney NL, Litt MD, Cooney JL, Pilkey DT, Steinburg HR, Oncken CA. Alcohol and tobacco cessation in alcohol-dependent smokers: Analysis of real-time reports. *Psychology of Addictive Behaviors*. 2007; 21:277–286. [PubMed: 17874878]
- IBM Corp Released. IBM SPSS statistics for windows, version 20.0. Armonk, NY: IBM Corp; 2011.
- Cox WM, Blount JP, Rozak AM. Alcohol abusers' and nonabusers' distraction by alcohol and concern-related stimuli. *American Journal of Drug and Alcohol Abuse*. 2000; 26:489–495. [PubMed: 10976671]
- Cox WM, Fadardi JS, Pothos EM. The addiction-Stroop test: Theoretical considerations and procedural recommendations. *Psychological Bulletin*. 2006; 132:443–456. [PubMed: 16719569]
- Cranwell J, Benford S, Houghton RJ, Golembewski M, Fischer JE, Hagger MS. Increasing self-regulatory energy using an Internet-based training application delivered by smartphone technology. *Cyberpsychology, Behavior, and Social Networking*. 2014; 17:181–186.
- DeWall CN, Baumeister RF, Vohs KD. Satiated with belongingness? Effects of acceptance, rejection, and task framing on self-regulatory performance. *Journal of Personality & Social Psychology*. 2008; 95:1367–1382. [PubMed: 19025289]
- El Khoury-Malhame M, Lanteaume L, Beetz EM, Roques J, Reynaud E, Samuelian JC, et al. Attentional bias in post-traumatic stress disorder diminishes after symptom amelioration. *Behaviour Research and Therapy*. 2011; 49:796–801. [PubMed: 21924404]
- First MB, Gibbon M. The structured clinical interview for DSM-IV Axis I disorders (SCID-I) and the structured clinical interview for DSM-IV Axis II disorders (SCID-II). 2004
- Foa EB, Feske U, Murdock TB, Kozak MJ, McCarthy PR. Processing of threat-related information in rape victims. *Journal of Abnormal Psychology*. 1991; 100:156–162. [PubMed: 2040766]
- Foa EB, Kozak MJ. Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin*. 1986; 99:20. [PubMed: 2871574]

- Ford JD. How can self-regulation enhance our understanding of trauma and dissociation? *Journal of Trauma & Dissociation*. 2013; 14:237–250. [PubMed: 23627475]
- Forster KI, Forster JC. DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers*. 2003; 35:116–124.
- Gonzalez C, Fuentes LJ, Carranza JA, Estevez AF. Temperament and attention in the self-regulation of 7-year-old children. *Personality and Individual Differences*. 2001; 30:931–946.
- Gray MJ, Litz BT, Hsu JL, Lombardo TW. Psychometric properties of the life events checklist. *Assessment*. 2004; 11:330–341. [PubMed: 15486169]
- Hagger MS, Leaver E, Esser K, Leung CM, Te Pas N, Keatley DA, et al. Cue-induced smoking urges deplete cigarette smokers' self-control resources. *Annals of Behavioral Medicine*. 2013; 46:394–400. [PubMed: 23720186]
- Houben K, Nederkoorn C, Wiers RW, Jansen A. Resisting temptation: Decreasing alcohol-related affect and drinking behavior by training response inhibition. *Drug & Alcohol Dependence*. 2011; 116:132–136. [PubMed: 21288663]
- Johnsen BH, Laberg JC, Cox WM, Vaksdal A, Hugdahl K. Alcoholic subjects' attentional bias in the processing of alcohol-related words. *Psychology of Addictive Behaviors*. 1994; 8:111–115.
- Judd CM, Westfall J, Kenny DA. Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology*. 2012; 103:54–69. [PubMed: 22612667]
- Kaspi SP, McNally RJ, Amir N. Cognitive processing of emotional information in posttraumatic stress disorder. *Cognitive Therapy and Research*. 1995; 19:433–444.
- Kaysen D, Atkins D, Simpson T, Stappenbeck C, Blayney J, Lee CM, et al. Proximal relationships between PTSD symptoms and drinking among female college students: Results from a daily monitoring study. *Psychology of Addictive Behaviors*. 2014; 28:62–73. [PubMed: 23915369]
- Khantzian EJ. The Self-Medication Hypothesis revisited: The dually-diagnosed patient. *Primary Psychiatry*. 2003; 1047:53–54.
- Killgore WDS. The affect grid: A moderately valid, nonspecific measure of pleasure and arousal. *Psychological Reports*. 1998; 83:639–642. [PubMed: 9819938]
- Killgore WDS. Affective valence and arousal in self-rated depression and anxiety. *Perceptual and Motor Skills*. 1999; 89:301–304. [PubMed: 10544430]
- Kimble MO, Frueh BC, Marks L. Does the modified Stroop effect exist in PTSD? Evidence from dissertation abstracts and the peer reviewed literature. *Journal of Anxiety Disorders*. 2009; 23:650–655. [PubMed: 19272751]
- Kline A, Weiner MD, Ciccone DS, Interian A, Hill LS, Losonczy M. Increased risk of alcohol dependency in a cohort of national guard troops with PTSD: A longitudinal study. *Journal of Psychiatric Research*. 2014; 50:18–25. [PubMed: 24332924]
- Kolassa IT, Ertl V, Eckart C, Kolassa S, Onyut LP, Elbert T. Spontaneous remission from PTSD depends on the number of traumatic event types experienced. *Psychological Trauma: Theory, Research, Practice, and Policy*. 2010; 2:169.
- Krans J, Reinecke A, de Jong PJ, Näring G, Becker ES. Analogue trauma results in enhanced encoding of threat information at the expense of neutral information. *Journal of Anxiety Disorders*. 2012; 26:656–664. [PubMed: 22683945]
- Lang, AR., Patrick, CJ., Stritzke, WG. Alcohol and emotional response: A multidimensional-multilevel analysis. In: Leonard, KE., Blane, HT., editors. *Psychological theories of drinking and alcoholism*. 2nd. New York: Guilford Press; 1999. p. 328–371.
- Litz BT, Keane TM. Information processing in anxiety disorders: Application to the understanding of post-traumatic stress disorder. *Clinical Psychology Review*. 1989; 9(2):243–257.
- Lurquin JH, McFadden SL, Harbke CR. An electrophysiological investigation of the effects of social rejection on self control. *The Journal of Social Psychology*. 2014; 154(3):186. [PubMed: 24873022]
- Maisto, SA., Carey, KB., Bradizza, CM. Social learning theory. In: Leonard, E. Kenneth Blane, Howard, T., editors. *Psychological theories of drinking and alcoholism*. 2nd. Vol. 1999. Publisher: Guilford Press; 1999. p. 106–163.

- Marx BP, Heidt JM, Gold SD. Perceived uncontrollability and unpredictability, self-regulation, and sexual revictimization. *Review of General Psychology*. 2005; 9:67–90.
- McNally RJ, Amir N, Lipke HJ. Subliminal processing of threat cues in posttraumatic stress disorder? *Journal of Anxiety Disorders*. 1996; 10:115–128.
- Miller MW, Vogt DS, Mozley SL, Kaloupek DG, Keane TM. PTSD and substance-related problems: The mediating roles of disconstraint and negative emotionality. *Journal of Abnormal Psychology*. 2006; 115:369–376. [PubMed: 16737401]
- Monti PM, Rohsenow DJ, Hutchison KE. Toward bridging the gap between biological, psychobiological, and psychosocial models of alcohol craving. *Addiction*. 2000; 95:229–236. [PubMed: 10723851]
- Moos, RH. Processes that promote recovery from addictive disorders. In: Kelly, JF., White, WL., editors. *Addiction recovery management*. Humana Press; 2010. p. 45–66.
- New AS, Fan J, Murrough JW, Liu X, Liebman RE, Guise T, et al. A functional magnetic resonance imaging study of deliberate emotion regulation in resilience and posttraumatic stress disorder. *Biological Psychiatry*. 2009; 66:656–664. [PubMed: 19589502]
- Ouimette PC, Moos RH, Finney JW. Two-year mental health service use and the course of remission in patients with substance use and post-traumatic stress disorders. *Journal of Studies on Alcohol*. 2000; 61:247–253. [PubMed: 10757135]
- Palfai TP. Automatic processes in self-regulation: Implications for alcohol interventions. *Cognitive and Behavioral Practice*. 2004; 1:190–201.
- Palfai, TP. Automatic processes in the self-regulation of addictive behaviors. In: Wiers, RW., Stacy, AW., editors. *Handbook of implicit cognition and addiction*. Thousand Oaks, CA: Sage Publications; 2006. p. 411–424.
- Pineles SL, Shipherd JC, Mostoufi SM, Abramovitz SM, Yovel I. Attentional biases in PTSD: More evidence for interference. *Behaviour Research and Therapy*. 2009; 47:1050–1057. [PubMed: 19716122]
- Protopapas A. Check vocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods*. 2007; 39:859–862. [PubMed: 18183901]
- Read JP, Coffey SF. Affective responses to trauma words Unpublished raw data. 2009
- Read JP, Merrill JE, Griffin MJ, Bachrach RL, Khan SN. Post-traumatic stress symptoms and alcohol problems: Self-medication or trait vulnerability? *The American Journal on Addictions*. 2014; 23:108–116. [PubMed: 25187046]
- Read JP, Ouimette P, White J, Colder C, Farrow S. Rates of DSM–IV–TR trauma exposure and posttraumatic stress disorder among newly matriculated college students. *Psychological Trauma: Theory, Research, Practice, and Policy*. 2011; 3:148–156.
- Read JP, Wardell JD, Colder CR. Reciprocal associations between PTSD symptoms and alcohol involvement in college: A three-year trait-state-error analysis. *Journal of Abnormal Psychology*. 2013; 122:984–997. [PubMed: 24364601]
- Rohsenow DJ, Monti PM, Abrams DB, Rubonis AV. Cue elicited urge to drink and salivation in alcoholics: Relationship to individual differences. *Advances in Behaviour Research and Therapy*. 1992; 14:195–210.
- Russell J, Weiss A, Mendelsohn G. Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology*. 1989; 57:493–502.
- Sayette MA, Hufford MR. Effects of smoking urge on generation of smoking-related Information1. *Journal of Applied Social Psychology*. 1997; 27:1395–1405.
- Sayette MA, Monti PM, Rohsenow DJ, Gulliver SB, Colby SM, Sirota AD, et al. The effects of cue exposure on reaction time in male alcoholics. *Journal of Studies on Alcohol*. 1994; 55:629–633. [PubMed: 7990473]
- Sobell, LC., Sobell, MB. Measuring alcohol consumption. Humana Press; 1992. Timeline follow-back; p. 41–72.
- Sobell LC, Sobell MB, Leo GI, Cancilla A. Reliability of a timeline method: Assessing normal drinkers' reports of recent drinking and a comparative evaluation across several populations. *British Journal of Addiction*. 1988; 83:393–402. [PubMed: 3395719]

- Stasiewicz PR, Maisto SA. Two-factor avoidance theory: The role of negative affect in the maintenance of substance use and substance use disorders. *Behavior Therapy*. 1993; 24:337–356.
- Stewart SH. Alcohol abuse in individuals exposed to trauma: A critical review. *Psychological Bulletin*. 1996; 120:83–112. [PubMed: 8711018]
- Stewart SH, Hall E, Wilkie H, Birch C. Affective priming of alcohol schema in coping and enhancement motivated drinkers. *Cognitive Behaviour Therapy*. 2002; 31(2):68–80.
- Stroop JR. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*. 1935; 18:643–662.
- Vinci C, Peltier MR, Shah S, Kinsaul J, Waldo K, McVay MA, et al. Effects of a brief mindfulness intervention on negative affect and urge to drink among college student drinkers. *Behavior Research and Therapy*. 2014; 59:82–93.
- Wardell JD, Ramchandani VA, Hendershot CS. A multilevel structural equation model of within-and between-person associations among subjective responses to alcohol, craving, and laboratory alcohol self-administration. *Journal of Abnormal Psychology*. 2015; 124:1050. [PubMed: 26595481]
- Wardell JD, Read JP. Does cue context matter? Examining the specificity of cue-related activation of positive and negative alcohol expectancies. *Experimental and Clinical Psychopharmacology*. 2013; 21:457–466. [PubMed: 24099353]
- Waters AJ, Shiffman S, Sayette MA, Paty JA, Gwaltney CJ, Balabanis MH. Attentional bias predicts outcome in smoking cessation. *Health Psychology*. 2003; 22:378. [PubMed: 12940394]

Fig. 1. Model implied means for overall Stroop reaction times (ms) by PTSD status and cue condition.

Fig. 2.

Simple slopes for the association between overall Stroop reaction time and post-cue urge to drink alcohol by cue condition and PTSD status.

Table 1

Descriptive statistics by cue condition and PTSD status.

Variables	Cue Condition		PTSD Status			
	Trauma <i>M</i> (<i>SD</i>) or <i>n</i> (%)	Neutral <i>M</i> (<i>SD</i>) or <i>n</i> (%)	<i>F</i> / <i>t</i> / χ^2 test	PTSD + <i>M</i> (<i>SD</i>) or <i>n</i> (%)	(%) PTSD- <i>M</i> (<i>SD</i>) or <i>n</i> (%)	Trauma- <i>M</i> (<i>SD</i>) or <i>n</i> (%)
Trauma Cue Condition	111 (100%)	0 (0%)	-	14 (50%)	51 (45%)	46 (51%)
Gender (Female)	53 (48%)	50 (50%)	0.17	21 ^a (75%)	54 ^b (48%)	39 ^b (43%)
PTSD Symptoms	0.47 (1.05)	0.50 (1.20)	0.20	3.40 ^a (0.80)	0.12 ^b (0.20)	0.04 ^b (0.12)
Number of Events on LEC	6.59 (4.79)	7.16 (6.25)	0.78	11.18 ^a (10.54)	7.42 ^b (4.48)	4.89 ^c (3.46)
Past 90 Day Total Alcohol Quantity	113.98 (117.93)	111.90 (106.51)	-0.14	174.81 ^a (162.46)	110.89 ^b (104.43)	96.34 ^b (95.71)
Pre-Cue Valence	6.21 (1.72)	5.88 (1.82)	-1.39	5.71 (2.05)	5.88 (1.87)	6.34 (1.52)
Pre-Cue Arousal	4.77 (1.77)	4.82 (1.62)	0.20	5.00 (1.94)	4.74 (1.67)	4.80 (1.66)
Pre-Cue Urge to Drink	2.01 (1.70)	2.37 (1.91)	1.52	2.93 ^a (2.24)	2.40 ^{a,b} (1.94)	1.73 ^b (1.36)
Mean Post-Cue Valence	3.59 (1.61)	5.88 (1.47)	11.38 ^{**}	4.09 ^a (1.91)	4.64 ^{a,b} (1.91)	5.18 ^b (1.86)
Mean Post-Cue Arousal	4.90 (1.61)	4.44 (1.42)	-2.31 [*]	5.31 ^a (1.88)	4.73 ^{a,b} (1.51)	4.36 ^b (1.38)
End Urge to Drink	2.811 (2.33)	2.58 (2.07)	-0.80	3.71 ^a (2.69)	2.84 ^{a,b} (2.22)	2.19 ^b (1.86)

Note. Trauma: *n* = 121, PTSD+: *n* = 28, PTSD-: *n* = 113, Trauma-: *n* = 91. Past 90 day total alcohol quantity is the sum of all standard drinks reported over the 90 day period. For significant omnibus differences across PTSD groups, means and percentages that do not share superscript letters differ significantly from one another, based on Tukey's tests.

* *p* 0.05,

** *p* 0.01.

Table 2

Results of multilevel regression model predicting overall stroop reaction times (ms) with word type interactions removed.

Fixed Effects	B	SE(B)	p
Level 1			
Word type contrasts:			
Trauma vs. furniture	29.52 **	8.07	<0.01
Alcohol vs. furniture	52.67 **	8.20	<0.01
Negative vs. furniture	14.61	8.12	0.07
Non-alcohol beverage vs. furniture	28.43 **	8.30	<0.01
Block position	12.34 **	1.54	<0.01
Post-cue valence ratings (person lefted)	-4.06 *	1.97	0.04
Post-cue arousal ratings (person lefted)	-0.27	1.45	0.85
Level 2			
Mean post-cue valence ratings (grand mean lefted)	-2.55	4.43	0.57
Mean post-cue arousal ratings (grand mean lefted)	0.66	4.52	0.88
Cue condition (0 = neutral, 1 = trauma)	36.81 *	18.86	0.05
PTSD status:			
Contrast 1: PTSD + vs. PTSD- and Trauma-	-12.29	18.46	0.50
Contrast 2: PTSD- vs. Trauma-	-1.22	19.52	0.95
Interactions			
PTSD Contrast 1 * Cue condition	52.42 *	26.76	0.05
PTSD Contrast 2 * Cue condition	11.11	28.26	0.70

Note.

**
p 0.01,

*
p 0.05.

Regression model predicting end of experiment urges to drink alcohol following the cue exposure and stroop task from overall reaction times (ms) Collapsed across word types.

Table 3

	B	SE(B)	p
Pre-cue urge to drink alcohol	1.19**	0.14	<0.001
Past 90-day alcohol quantity	0.06	0.14	0.678
End of experiment valence ratings	-0.24	0.14	0.088
End of experiment arousal ratings	0.17	0.13	0.191
Cue condition (0 = neutral, 1 = trauma)	-0.08	0.31	0.794
PTSD Contrast 1: PTSD + vs. PTSD- and Trauma-	0.65	0.36	0.071
PTSD Contrast 2: PTSD- vs. Trauma-	-0.02	0.37	0.953
Overall Stroop RT	-0.23	0.19	0.230
Cue condition * PTSD Contrast 1	-1.08*	0.52	0.038
Cue condition * PTSD Contrast 2	0.40	0.53	0.455
Cue condition * Overall Stroop RT	0.47	0.26	0.077
PTSD Contrast 1 * Overall Stroop RT	-0.15	0.29	0.608
PTSD Contrast 2 * Overall Stroop RT	-0.35	0.44	0.421
Cue condition * PTSD Contrast 1 * Overall Stroop RT	0.91*	0.41	0.027
Cue condition * PTSD Contrast 2 * Overall Stroop RT	0.25	0.57	0.668

Note. RT = Reaction Time (ms). Pre-cue urge to drink alcohol, past 90-day alcohol quantity, and All continuous variables were standardized across participants. $P < 0.01$

* $p < 0.05$.