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Alcohol consumption as a predictor of reactivity to smoking and stress cues presented in the natural environment of smokers

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Abstract

Background and rationale—The high prevalence of co-occurring alcohol and tobacco use underscores the importance of understanding the influence of alcohol consumption on risk factors for smoking and relapse. Alcohol has been shown to impact reactivity to smoking and stress-related cues, both of which are common antecedents to smoking and smoking relapse.

Objective—The objective of the current study is to examine associations between alcohol use, cigarette craving, and stress reactivity following exposure to smoking and stress cues delivered in participants' daily lives.

Methods—Using cue-reactivity ecological momentary assessment (CREMA), adult smokers (n = 138) reported cigarette craving, stress, and past hour alcohol use on a mobile device four times per day for 2 weeks, resulting in a range of 4493–5983 data points per analysis. Questions were followed by exposure to pictorial neutral, stressful, or smoking cues delivered via the mobile device. Craving and affect were reassessed following cue exposure.

Results—Results showed that recent (past hour) alcohol use was significantly associated with increases in the following: (a) tonic (non-cue-elicited) cigarette craving, (b) stress cue-elicited cigarette craving, and (c) stress cue-elicited stress reactivity, in the context of high-baseline stress. There was no significant association between alcohol use and smoking cue-elicited craving.

Conclusions—Alcohol use may increase risk for smoking and relapse to smoking by increasing cigarette craving and, in certain contexts, stress following stress cue exposure. Though alcohol is known for its anxiolytic properties, under some conditions, it may increase reactivity to stress cues.

Conflict of interest The authors declare that they have no conflict of interest.

Keywords

Tobacco; Alcohol; Cue reactivity; Ecological momentary assessment; Stress

More than 70% of cigarette smokers consume alcohol (Anthony and Echeagaray-Wagner 2000; Falk et al. 2006), often in greater quantities than non-smokers (McKee et al. 2007). People attempting to quit smoking may be four times more likely to lapse/relapse on days which they have consumed alcohol (Kahler et al. 2010; see also, Shiffman et al. 1996).

The mechanisms by which alcohol consumption increases likelihood of smoking or relapse are likely multifaceted, but one possibility is that alcohol increases tonic, or non-cue-elicited, cigarette craving and cue-elicited craving. Alcohol consumption is related to increased tonic/non-cue-elicited cigarette craving in both laboratory studies (Burton and Tiffany 1997; King et al. 2009; King and Epstein 2005; Sayette et al. 2005) and naturalistic studies (Businelle et al. 2013; Delfino et al. 2001; Piasecki et al. 2008). Cigarette craving also increases when a smoker is exposed to smoking cues (e.g., Carter and Tiffany 1999; LaRowe et al. 2007), and alcohol consumption may increase reactivity to smoking cues (Sayette et al. 2005). Cross-cue reactivity is presumed to develop when substances are repeatedly used together, so that the individual learns to associate one substance with the other. For example, exposure to alcohol cues may increase cigarette craving (Drobes 2002). By definition, alcohol consumption involves exposure to alcohol cues, which include both exteroceptive cues (for example, visual and olfactory stimuli) and interoceptive cues (e.g., the subjectively discernable effects of alcohol ingestion). To the extent these cues are routinely associated with cigarette smoking, alcohol may serve to intensify the cue-specific reactions generated by cigarette stimuli. However, laboratory-based studies examining the effects of alcohol consumption on reactivity to smoking cues have produced mixed results (Burton and Tiffany 1997; Sayette et al. 2005). To date, no studies have examined the effect of alcohol consumption on cue-induced craving outside of the laboratory.

Though alcohol use may exacerbate smoking cue-elicited craving, alcohol use may also alleviate stress (see Sher and Grekin 2007, for a review). Because exposure to a stressor may result in increased cigarette craving (e.g., Childs and De Wit 2010; Saladin et al. 2012; Tiffany and Drobes 1990), the stress-reducing properties of alcohol could result in attenuated stress-related cigarette craving. Many drinkers report motivation to use alcohol in order to alleviate stress and other aversive states (Cooper et al. 1995). However, laboratory studies examining whether alcohol use effectively reduces stress response have produced mixed results, suggesting that the relationship between alcohol use and stress reduction is complex. Stress reduction is most likely when alcohol use precedes the onset of the stressor (Sayette 1993; Sayette et al. 2001). Alcohol is also more likely to reduce stress when distractions are available, presumably by drawing finite attentional resources away from the stressor (Steele and Josephs 1990). Because stress is also a motivator for smoking among regular smokers (Kassel et al. 2003), reduced stress response as a result of alcohol consumption could hypothetically lead to reduced stress-reactive craving for cigarettes.

Research examining alcohol's impact on reactivity to smoking cues and stressors has been conducted almost exclusively in laboratory settings. However, it is important to examine the

situations in which findings from laboratory-based research generalize to real-world settings. Ecological momentary assessment (EMA; Stone and Shiffman 1994) involves repeated assessments of an individual in his or her natural environment, during typical daily routines. Therefore, EMA can be used to assess the external validity of relationships established under controlled laboratory conditions that favor internal validity.

The current study combined EMA-based methods with a novel cue-reactivity paradigm (cue reactivity ecological momentary assessment, CREMA; Warthen and Tiffany 2009; Wray et al. 2011; Wray et al. 2015) in which pictorial cues are administered via an electronic device to participants in their natural environments in conjunction with EMA-based assessments. Our goal was to examine associations between alcohol consumption, tonic (non-cue-elicited) cigarette craving, and responses to smoking and stress cues presented in the natural environment of adult smokers via CREMA. We hypothesized that recent, i.e., past-hour alcohol consumption, would be associated with the following: (1) increased tonic cigarette craving, (2) increased cigarette craving following exposure to pictorial smoking cues, and (3) decreased subjective stress and cigarette craving following exposure to pictorial stress cues. An exploratory analysis is also conducted examining the association between recent alcohol consumption and non-cue-elicited stress.

Method

Participants

Adult smokers (n = 143) ages 18 to 45 were recruited from the community via internet, bus, and television advertisements, flyers, and participant referrals. Individuals were eligible for inclusion if they smoked five or more cigarettes per day in the past 6 months and provided a carbon monoxide (CO) sample with a level of ≥5 ppm at screening. Smokers were excluded if they were regular users of (or unwilling to abstain from) tobacco products other than cigarettes, including e-cigarettes. Smokers who met the criteria for DSM-IV-TR substance dependence (other than nicotine or caffeine dependence) were excluded. Smokers were also excluded if they presented with unstable medical or psychiatric comorbidity, assessed by a medical clinician and the Mini-International Neuropsychiatric Interview (Sheehan et al. 1998), respectively. Participants were recruited for an ongoing parent study focused on hormonal influences on stress, craving, and smoking. Therefore, female participants were excluded if they were using birth control or hormone replacement medication, were breastfeeding, or reported irregular menstrual cycles.

Procedures and measures

Study procedures have been described in detail elsewhere (Wray et al. 2015). Briefly, participants completed laboratory visits on four occasions: screening visit, CREMA orientation visit, mid-study visit, and final visit. During the screening visit, participants were evaluated for eligibility and completed baseline questionnaires. At the CREMA orientation visit, participants received instruction on how to complete CREMA sessions. Participants were provided with an iPhone 4 s in order to complete the sessions if they did not own a compatible device or did not wish to use their own device. The mid-study visit was conducted approximately 1 week after initiation of the 2-week CREMA protocol. The final

visit occurred after 2 weeks of daily CREMA sessions (14 days). Participants returned any borrowed devices and completed other laboratory tasks related to the aims of the parent study.

Baseline self-report of alcohol and cigarette use—The *Timeline follow-back* (TLFB; Sobell and Sobell 1992) was used to assess quantity and frequency of past 30-day smoking and alcohol use. For number of drinks consumed, participants were educated on the definition of a standard drink (i.e., 12 oz of beer, 1.5 oz of liquor, 5 oz of wine). The *Fagerström test for nicotine dependence* (FTND; Heatherton et al. 1991), a 6-item interview-administered questionnaire, was used to assess subjective dependence on nicotine.

Cue reactivity ecological momentary assessment protocol (Warthen and Tiffany 2009; Wray et al. 2011; Wray et al. 2015)—CREMA is an EMA-based cue reactivity assessment in which photos are presented multiple times per day on a mobile electronic device (i.e., Palm Pilot or iPhone). The CREMA protocol involved the presentation of smoking (e.g., person holding a cigarette), stress-related (e.g., bodily disfigurement, a child in distress), and neutral (e.g., a pair of sunglasses) picture cues in real-world settings (Warthen and Tiffany 2009; Wray et al. 2011; Wray et al. 2015). Most smoking (30) and neutral (28) photos were selected for and/or previously utilized in CREMA studies (Warthen and Tiffany 2009; Wray et al. 2011); however, 12 additional smoking photos were identified locally for the purpose of this study. Stressful photos (42) were obtained from the International Affective Picture System (IAPS; Lang et al. 2008). Each image was shown to each participant exactly one time, ensuring the novelty of all stimuli.

Participants completed a morning report of number of cigarettes smoked and standard alcoholic drinks consumed in the past 24 h. Following the morning report, the next 12 h were stratified into four 3-h blocks and participants were prompted to complete a CREMA assessment at a randomly selected time during each block. When prompted, participants completed baseline assessments of stress (single item on a 1–5 Likert scale) and cigarette craving (4-items on a 1–5 Likert scale; Craving questionnaire; Carter and Tiffany 2001), alcohol use in the past hour (yes/no), and time since last cigarette (in minutes). Then, participants were shown a smoking, stressful, or neutral cue for 10 s. Following the cue, participants were asked to re-rate their stress and craving for cigarettes. Integrity of cue manipulation was verified by asking each participant, following each cue, if they were able to view the photograph and if they were distracted during viewing. This cue exposure procedure was repeated twice during each session so that two different cue types were presented per session, resulting in a total of eight presented cues per day. Though cue presentation was randomized, the schedule was designed to ensure that a consistent number of smoking (3), stressful (3), and neutral (2) cues were presented each day.

Data analytic procedure

Study data were uploaded from mobile devices and managed using research electronic data capture (REDCap) tools (Harris et al. 2009) hosted by the South Carolina Clinical and Translational Research Institute at the Medical University of South Carolina. Demographic

and clinical characteristics are tabulated for each randomized participant. To test the primary hypothesis that recent alcohol consumption was related to cigarette craving and cue response (i.e., cigarette craving, cue reactivity), multilevel models (MLM) were employed (3-level random effect model). This approach is ideal for analysis of EMA data as it can accommodate unequally spaced time intervals, missing data, and varying numbers of observations across participants while accounting for within-subject variance (Gibbons et al. 2010). The data were structured such that, for each subject, multiple CREMA sessions were taken each day for (up to) 14 days. Level 1 (event level) consisted of the momentary assessments for each person, such as past hour alcohol use, time since last cigarette, and baseline stress, and allows for the estimation of within-individual variability. Level 2 represented the day level; however, no day-level predictors were used except in the post hoc examination of heavy drinking days. Level 3 consisted of person-level variables, such as sex, FTND score, and average baseline craving, and allows for the estimation of between-individual variability. The model building process was done in a way that provided a parsimonious model that also fit the data well. Random intercepts were modeled at levels 2 and 3. The method of residual maximum likelihood (REML; Patterson and Thompson 1971) was used to produce unbiased variance estimation.

Alcohol consumption (in the preceding hour) was assessed and coded as a binary variable (0.1) and was centered around each participants' mean alcohol consumption (i.e., the proportion of assessments preceded by alcohol consumption). Pre-cue craving and stress were centered around each participants' mean pre-cue craving and stress scores, respectively (for applicable models). Though the primary variables of interest were observation level predictors (i.e., alcohol consumption), participant level variables including sex, frequency of drinking (person-average of session alcohol consumption variable), average baseline craving (person-average of pre-cue craving ratings), and baseline nicotine dependence (FTND) were included as covariates. Frequency of alcohol use, FTND score, and average baseline craving were grand mean-centered. Baseline average cigarettes per day (TLFB) was also considered for inclusion as a covariate; however, due to the high correlation between average cigarettes per day and FTND scores ($r = 0.48$), only the FTND score was included in analyses. FTND was chosen rather than average number of cigarettes per day as frequency of use was likely reflected by the inclusion of minutes since last cigarette in the model. Likewise, baseline alcohol use frequency (TLFB) was considered for inclusion in the model; however, this was highly correlated with frequency of drinking throughout the study ($r = 0.57$). Data are presented as model-based beta estimates and associated standard errors unless otherwise noted. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc 2012), and no corrections for multiple testing are made to the presented results.

Results

Compliance with CREMA protocol and quality checks

Participants were retained in the final analyses if they completed at least one full week of CREMA sessions; five participants failed to provide at least one full week of data. The resulting sample size for data analysis was 138 adult smokers. The final sample was over-

sampled for females (58.7% of the final sample) due to the aims of the parent study. Other demographics and baseline substance use characteristics are presented in Table 1.

On average, individuals completed 80.1% (SD = 15.6) of their administered CREMA sessions which resulted in an average of 43.4 sessions per person. The maximum possible number of sessions per person was 56 (14 days × 4 prompts each). Compliance did not significantly differ by sex or drinking status. We chose not to exclude participants below a minimum rate of compliance in order to maximize our sample size.

Across all completed CREMA trials (n = 12,146), participants reported that they were unable to see 1.4% (n = 172) of the cues, purportedly due to technical issues with the CREMA app or the participant's mobile device. These trials were removed from subsequent analysis, resulting in a final sample of 11,974 usable cue presentations (4499 smoking, 4493 stressful, and 2982 neutral) across 138 participants.

Descriptive statistics from morning report and CREMA sessions

Alcohol use and smoking behavior—Nighty-eight (n = 98) participants (71.0% of sample) reported alcohol use during the 2-week study period via morning report and/or during a CREMA session. Morning report data were used to categorize the previous day as an "alcohol day" or "no-alcohol day." There were 340 total "alcohol days" based on participants' morning reports and 290 CREMA sessions during which participants reported recent alcohol consumption (resulting in 580 trials). Stratified random CREMA sampling was considered to have "captured" daily alcohol consumption on an "alcohol day" if alcohol use was reported within the past hour for at least one of the four CREMA sessions delivered that day. Alcohol use was reported within the hour prior to at least one CREMA session for 38.3% of alcohol days. An average of 3.11 (SD = 2.90) standard drinks were reported per alcohol day (with a maximum possible report of 20 drinks per day). Significantly more standard drinks were consumed (t = 4.63, df = 193.14, p < 0.01) on alcohol days when a CREMA session captured alcohol use (M = 4.12, SE = 0.31) vs. alcohol days on which no CREMA sessions captured alcohol use (M = 2.52, SE = 0.16).

Participants reported smoking an average of 13.8 cigarettes per day (SD = 6.6; Range 1–41) via morning reports. During CREMA sessions, participants reported that they smoked their last cigarette 48.9 min before the session, on average (SD = 96.7).

Pre- and post-cue stress and craving—Prior to cue exposure, the average pre-cue stress across all sessions (n = 5983) was 1.69 (SD = 1.09; Range = 1–5). The average post-cue stress was 1.56 (SD = 1.00) and 2.02 (SD = 1.23) for smoking and stress cues, respectively. The average pre-cue craving was 9.4 (SD = 5.31; range = 4–20). The average post-cue craving was 10.34 (SD = 5.43) and 7.40 (SD = 5.43) for smoking and stress cues, respectively.

Alcohol consumption as a predictor of tonic cigarette craving and stress

With minutes since last cigarette, day vs. evening (0/1), sex, frequency of alcohol use during study period, average baseline craving during the study period, and FTND score included in the model, alcohol use in the past hour was associated with significantly greater tonic

cigarette craving ($b = 0.96$, SE = 0.26, $p < 0.001$) as reported pre-cue administration. The full model (based on 5983 baseline assessments) is presented in Table 2.

With minutes since last cigarette, day vs. evening (0/1), sex, frequency of alcohol use during study period, average baseline craving during the study period, and FTND score included in the model, alcohol use in the past hour was associated with significantly less baseline stress ($b = -0.18$, SE = 0.06, $p = 0.002$) as reported pre-cue administration (see Table 3).

Alcohol consumption as a predictor of reactivity to CREMA cues

As shown in Table 4, alcohol use in the past hour was not associated with increased craving following smoking cue administration ($b = 0.34$, SE = 0.24, $p = 0.16$). The interaction between baseline craving and past hour alcohol use was examined, but was not significant and dropped from the final model. Individuals with greater FTND scores ($b = 0.16$, SE = 0.07, $p = 0.02$), individuals with higher average craving ($b = 0.95$, SE = 0.04, $p < 0.01$), and individuals with more frequent alcohol consumptions ($b = 3.40$, SE = 1.57, $p = 0.03$) reported greater cigarette craving following smoking cue exposure, even after controlling for baseline craving.

Alcohol use moderated the relationship between baseline stress and stress following exposure to stressful cues ($b = 0.18$, SE = 0.08, $p = 0.03$). This interaction was explored through the generation of a dichotomous variable corresponding to low (below or equal to a person's mean) and high (above a person's mean) baseline stress. When baseline stress was high and alcohol had been consumed in the past hour, stress ratings following stressful cues were increased. When baseline stress was low, this effect was diminished. Males ($b = -0.26$, SE = 0.10, $p < 0.01$) were less likely to exhibit increased stress following stress-cue presentation, while individuals reporting a greater frequency of drinking days ($b = 1.28$, SE = 0.54, $p = 0.02$) or higher general stress during the study period ($b = 0.92$, SE = 0.08, $p < 0.01$) were more likely to report increased stress following exposure to stressful cues.

The interaction between baseline craving and past hour alcohol use did not significantly predict post-stress cue craving, and the term was dropped from the final model. Alcohol use significantly predicted craving following exposure to stressful cues ($b = 0.65$, SE = 0.26, $p = 0.01$). Males were less likely to endorse craving following exposure to stress cues than females ($b = -0.81$, SE = 0.37, $p = 0.03$). Similar to craving post-smoking cues, individuals with greater FTND scores ($b = 0.23$, SE = 0.09, $p = 0.01$), individuals with higher average craving ($b = 0.55$, SE = 0.05, $p < 0.01$), and individuals with a greater frequency of alcohol consumption ($b = 4.74$, SE = 2.11, $p = 0.03$) reported greater cigarette craving following stress cue exposure, even after controlling for baseline craving.

Discussion

This study utilized a novel and real-world cue reactivity paradigm (CREMA) to examine associations between alcohol consumption and tonic (non-cue-elicited) and cue-elicited cigarette craving. First, we attempted to replicate the positive association between alcohol consumption and reported tonic craving for cigarettes using real-time assessments in smokers' daily lives. Consistent with both our hypothesis and previous EMA research

(Businelle et al. 2013; Delfino et al. 2001; Piasecki et al. 2008), results suggested that alcohol consumption was associated with increased tonic craving for cigarettes. An exploratory analysis examining the association between recent alcohol consumption and reported pre-cue stress suggested that subjective stress was decreased compared to an individual's typical level of stress, following alcohol consumption. This may indicate either that (a) smokers are more likely to consume alcohol when stress is low, or (b) alcohol use reduces subjective stress.

Second, we hypothesized that alcohol consumption would be followed by greater smoking cue-elicited craving; however, this hypothesis was not supported. The lack of a main effect of alcohol on cue-elicited cigarette craving is consistent with some research (Burton and Tiffany 1997), but not all (Sayette et al. 2005). This discrepancy may be due to methodological differences, in that the latter required a 12-h abstinence from smoking prior to the protocol and provided less intense cue exposure. As previously mentioned, though, tonic cigarette craving was elevated following alcohol consumption. It is possible that this elevated tonic cigarette craving limited the possibility for increased craving following smoking cue exposure (i.e., ceiling effect).

Third, we hypothesized that alcohol consumption would be associated with decreased stress cue-elicited stress and craving. Contrary to this hypothesis, alcohol consumption prior to exposure to stressful cues was associated with increased stress reactivity, when baseline stress was high, and increased post-cue cigarette craving. The finding that alcohol consumption was associated with greater reactivity to stress cues in the context of high baseline stress can be interpreted with regard to existing models on alcohol and tension reduction. Sayette (1993) proposed that when alcohol use precedes the onset of a stressor, alcohol interferes with activation of associated learning networks and prevents negative appraisal of a stressor (i.e., appraisal-disruption model). However, if stress precedes alcohol use, stress may be exacerbated as alcohol "narrows" attention to the most salient stimuli (Steele and Josephs 1990). It follows that stress-related craving would be increased if stress increased.

Several limitations must be considered when interpreting the results. First, it is likely that real-world craving and stress is determined by a multitude of factors exerting small effects, with alcohol consumption being one of many of such factors. Second, it was not possible to determine the exact timing of alcohol consumption prior to cue administration. Relatedly, because quantity of alcohol consumed was not assessed prior to the CREMA sessions, we were unable to examine the effect of alcohol across a continuum of consumption. Higher blood alcohol levels may influence cue-elicited craving in different ways than do lower levels. Future research should combine CREMA-based assessment with event-based reports of alcohol and cigarette use. Alternatively, passive measures of alcohol and cigarette use (e.g., transdermal monitors) might be used to examine real-world associations between smoking, smoking and stress-related cue reactivity, and blood alcohol level. Third, this study relied solely on subjective reports of craving, stress, smoking, and alcohol use. EMA has the advantage of requiring retrospection over only short periods of time (in this study, several hours), minimizing recall biases inherent in self-report. However, self-report has a number of additional limitations, most notably social desirability biases and reliance on participant

awareness (Nisbett and Wilson 1977). A multimethod assessment that incorporates subjective and physiological measures of cue reactivity, substance use, and stress may be optimal, particularly in a real-world context in which experimental control is limited. Fourth, despite the fact that alcohol use preceded the CREMA sessions, it is not possible to infer that alcohol use had a causal effect on cue reactivity. Indeed, other risk factors such as pre-existing stress or cigarette craving may have increased likelihood of alcohol consumption, and may also explain participants' varying reactivity to cues. Fifth, though this study took place in a "real-world" context, the smoking and stressful cues administered may have varied in their personal relevance to the participants. Because cue-induced craving evokes learned associations between the cue and previous experience with cigarettes (or other drugs), the personal relevance of cues varies with a person's past experiences. Additionally, the stressful cues administered in this study were not representative of the broad range of stressors that individuals might experience in daily life (i.e., may have limited ecological validity). Finally, the "stress cues" could arguably be termed "negative affect cues", particularly since they were derived from standardized IAPS stimuli. We chose to refer to the cues as "stress cues" because (1) we were interested in the construct of stress as an outcome, and (2) because the cues have been shown to result in heightened subjective stress (Wray et al. 2015). However, alcohol may have differential effects on subjective stress and negative affect, and future research with other types of stressors/cues is warranted to separate these effects.

Despite the aforementioned limitations, this study provided a novel examination of alcohol's effects on cue reactivity in naturalistic settings. While sacrificing some experimental control afforded by the laboratory setting, this real-world cue-reactivity paradigm has the advantage of providing information on how individuals react to smoking and stressful cues in environments in which they are able to select when and where they drink, and how much alcohol they wish to consume. Results of this study suggest that, in the real-world settings of daily smokers, alcohol consumption may increase tonic cigarette craving and reactivity to stressful cues. To the extent that tonic cigarette craving and stress reactivity are risk factors for lapse/relapse following cessation, the present findings would suggest that alcohol consumption should be avoided in those who are making a quit attempt. Additionally, this study suggests that alcohol consumption and exposure to stressors may be optimal contexts in which to deliver real-world interventions to prevent relapse following a quit attempt, including interventions delivered as needed via mobile health apps (Heron and Smyth 2010). Future research should examine specific conditions (e.g., location, activity, and context) in which alcohol consumption is likely to exacerbate stress reactivity and stress-related cigarette craving.

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Table 1

Baseline demographic and substance use information

	Total sample (*n* = 138)
Age	
M	30.5 (SD = 7.3)
% female	58.7
Race (%)	
White/Caucasian	51.5
Black/African–American	43.5
Biracial	3.6
Other	1.4
Marital Status (%)	
Single, divorced, separated, or widowed	86.2
Married	13.8
Currently unemployed (%)	34.8
Income less than $25,001 (%)[a]	64.5
Substance use (prior to study enrollment)	
Average cigarettes/day (30-day TLFB)	14.9 (SD = 7.0)
Days consumed alcohol (30-day TLFB)	4.6 (SD = 6.0)
Average drinks/day (30-day TLFB)	0.6 (SD = 0.9)
Average drinks/drinking day (30-day TLFB)	3.22 (SD = 2.2)
Nicotine dependence (FTND)	4.7 (SD = 2.1)

[a]Income data not available for 2 participants

Table 2

Alcohol use as a predictor of tonic (baseline) craving (n = 5983)

	Full model			
	b	**SE**	**df**	***p* value**
Fixed effects				
Intercept	−0.30	0.19	133	0.110
Alcohol use	0.96	0.26	5842	<0.001**
Event-level covariates				
Time since smoked (min)	0.01	<0.01	5842	<0.001**
Day (after 4 PM = reference group)	0.05	0.10	137	0.613
Person-level covariates				
Sex (female = reference group)	0.04	0.12	133	0.740
FTND score	0.08	0.03	133	0.009**
Average baseline craving	0.99	0.02	133	<0.001**
Frequency of alcohol use	−0.19	0.68	133	0.778

Beta estimates are unstandardized. Number of drinking days (TLFB) is not included in model because it is highly correlated (r = 0.57) with the frequency of alcohol use variable (proportion of sessions which are preceded by drinking)

FTND Fagerström test for nicotine dependence

** Denotes p values less than 0.01

Table 3

Alcohol use as a predictor of baseline stress (n = 5983)

	Full model			
	b	**SE**	**df**	***p* value**
Fixed effects				
Intercept	−0.01	0.05	133	0.742
Alcohol use	−0.18	0.06	5842	0.002**
Event-level covariates				
Time since smoked (min)	<0.01	<0.01	5842	0.157
Day (after 4 PM = reference group)	0.07	0.02	137	0.773
Person-level covariates				
Sex (female = reference group)	0.01	0.03	133	0.854
FTND score	<0.01	0.01	133	0.690
Average baseline stress	1.00	0.02	133	<0.001**
Frequency of alcohol use	−0.04	0.16	133	0.817

Beta estimates are unstandardized. Number of drinking days (TLFB) is not included in model because it is highly correlated (r = 0.57) with the frequency of alcohol use variable (proportion of sessions which are preceded by drinking)

FTND Fagerström test for nicotine dependence

** Denotes p values less than 0.01

Table 4

Alcohol consumption as a predictor of CREMA cue reactivity (multilevel model fixed effects)

	Full models			
	b	**SE**	**df**	***p* value**
Cigarette craving following smoking cue trials (*n* = 4499)				
Intercept	1.17	0.42	133	0.006**
Alcohol use	0.34	0.24	4357	0.159
Event-level covariates				
Time since smoked (min)	<0.01	<0.01	4357	<0.001**
Baseline craving	0.58	0.01	4357	<0.001**
Day (after 4 PM = reference group)	0.02	0.10	135	0.868
Person-level covariates				
Sex (female = reference group)	−0.11	0.28	133	0.686
FTND score	0.16	0.07	133	0.016*
Average baseline craving	0.95	0.04	133	<0.001**
Frequency of alcohol use	3.40	1.57	133	0.033*
Stress reactivity following stress trials (*n* = 4493)				
	b	SE	df	*p* value
Intercept	0.52	0.15	133	<0.001**
Alcohol use	0.20	0.07	4350	0.005*
Alcohol use * baseline stress	0.18	0.08	4350	0.026*
Event-level covariates				
Time since smoked (min)	<−0.01	<0.01	4350	0.170
Baseline stress	0.28	0.02	4350	<0.001**
Day (after 4 PM = reference group)	0.03	0.03	136	0.370
Person-level covariates				
Sex (female = reference group)	−0.26	0.10	133	0.008**
FTND score	−0.02	0.02	133	0.303
Average baseline stress	0.92	0.08	133	<0.001**
Frequency of alcohol use	1.28	0.54	133	0.020*
Cigarette craving following stress trials (*n* = 4493)				
	b	SE	df	*p* value
Intercept	2.57	0.56	133	<0.001**
Alcohol use	0.65	0.26	4351	0.013*
Event-level covariates				
Time since smoked (min)	<0.01	<0.01	4351	0.604
Baseline craving	0.37	0.01	4351	<0.001**
Day (after 4 PM = reference group)	−0.18	0.11	136	0.093
Person-level covariates				

	Full models			
	b	**SE**	**df**	***p* value**
Sex (female = reference group)	−0.81	0.37	133	0.031*
FTND score	0.23	0.09	133	0.011*
Freq of alcohol use	4.74	2.11	133	0.026*
Avg baseline craving	0.55	0.05	133	<0.001**

Beta estimates are unstandardized

FTND Fagerström test for nicotine dependence, *TLFB* 30-day timeline followback

* Denotes *p*-values less than 0.05

** Denotes *p* values less than 0.01