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Cannabis craving in response to laboratory-induced social stress among racially diverse cannabis users: The impact of social anxiety disorder

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Abstract

Social anxiety disorder appears to be a risk factor for cannabis-related problems. Although it is presumed that increases in cannabis craving during elevated social anxiety reflect an intent to cope with greater negative affectivity, it is unclear whether increases in physiological arousal during social stress are related to cannabis craving, especially among those with social anxiety disorder. Similarly, no studies have assessed motivational reasons for cannabis use during elevated social stress. Thus, the current study tested whether increases in state social anxiety (measured subjectively and via physiological arousal) were related to greater cannabis craving among 126 current cannabis users (88.9% with cannabis use disorder, 31.7% with social anxiety disorder, 54.0% non-Hispanic Caucasian) randomly assigned to either a social interaction or reading task. As predicted, cannabis users in the social interaction condition reported greater cannabis craving than those in the reading condition. This effect was particularly evident among those with social anxiety disorder. Although physiological arousal did not moderate the relationship between condition and craving, coping motives were the most common reasons cited for wanting to use cannabis and were reported more among those in the social interaction task. These experimental results uniquely add to a growing literature suggesting the importance of elevated state social anxiety (especially among those with social anxiety disorder) in cannabis use vulnerability processes.

Keywords

Cannabis; marijuana; craving; social anxiety; psychophysiology

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Numerous lines of evidence suggest that social anxiety disorder (SAD) is associated with cannabis-related impairment. Compared to those without SAD, adolescents with SAD have nearly seven times greater risk of developing cannabis dependence in adulthood (Buckner et al., 2008). SAD is related to faster transition from first cannabis use to experiencing cannabis-related problems among males (Buckner et al., 2012c; Marmorstein et al., 2010). In fact, nearly one-third to one-fourth of people with cannabis dependence have SAD, a higher rate than for other anxiety disorders (Agosti et al., 2002; Stinson et al., 2006). The relation between social anxiety and cannabis problems remains after controlling for relevant variables (e.g. other substance use, other types of anxiety, depression; e.g. Buckner and Schmidt, 2009; Buckner et al., 2006; Buckner et al., 2008). The relation between social anxiety and cannabis use vulnerability factors appears highly clinically significant, as the co-occurrence of SAD and cannabis use disorders (CUD) is related to greater functional impairment and psychiatric problems than either disorder alone (Buckner et al., 2012c) and frequent cannabis users with elevated social anxiety demonstrate elevated suicidality (Buckner et al., 2012d).

Despite the high co-occurrence of SAD and cannabis-related problems, little empirical work has focused on identification of cannabis use vulnerability factors related to SAD. Available work indicates cannabis users with elevated social anxiety endorse more coping motivated use and coping motives mediate the relation between social anxiety and cannabis problems (Buckner et al., 2007). Social anxiety is also related to using cannabis to cope in social situations and avoiding social situations if cannabis is unavailable (Buckner et al., 2012b). Additionally, cannabidiol (CBD; an active component of cannabis) is associated with decreases in subjective (i.e. self-reported) levels of state social anxiety (Bergamaschi et al., 2011; Zuardi et al., 1993). In an ecological momentary assessment of “real-world” ad-lib cannabis use, use was most likely to occur in social situations (Buckner et al., 2012a). Moreover, SAD status moderated the relation between situation type (alone vs. social situations) and use, such that users with SAD in social situations were the most likely to use cannabis, suggesting that SAD users are vulnerable to use during periods of elevated state social anxiety.

Data from laboratory studies also support the notion that users with SAD are vulnerable to using cannabis during periods of elevated state social anxiety. Undergraduates with SAD (but not those without SAD) reported greater cannabis craving during (but not before or after) a speech task (Buckner et al., 2011). Among undergraduate cannabis users, cannabis craving increased from before to during the task among participants in the social interaction condition, but not among those in a control condition (Buckner et al., 2013). This effect was specific to cannabis craving and was not observed for craving for alcohol or cigarettes.

Together, past studies suggest that cannabis users appear vulnerable to using cannabis during periods of elevated social anxiety and that this may be especially the case among users with SAD. Yet, there remain several gaps in our understanding of the relationships between social anxiety (both elevated state social anxiety as well as elevated trait social anxiety, or SAD) and cannabis use vulnerability factors. First, although it is presumed that increases in cannabis craving during periods of elevated state social anxiety reflect a desire to cope with interoceptive cues of negative affectivity (e.g. physiological arousal related to state social

anxiety; see Baker et al., 2004), prior studies (Buckner et al., 2011; Buckner et al., 2013) did not evaluate whether increases in physiological arousal during a social stressor were related to greater cannabis craving among current cannabis users. Although one study found no effect of CDB on physiological responding during social stress (Zuardi et al., 1993), the sample was comprised of healthy individuals who did not use drugs, nor did they evince elevated social anxiety. Second, prior studies (Buckner et al., 2011; Buckner et al., 2013) did not assess motives for cannabis use during periods of laboratory-induced social stress. It is therefore unknown whether participants want to use cannabis to cope with elevations in state social anxiety (i.e. for coping motives), or to experience more positive emotions during unpleasant social situations (i.e. enhancement motives). Third, most extant experimental studies of cannabis–social anxiety relationships (Bergamaschi et al., 2011; Buckner et al., 2011; Zuardi et al., 1993) used speech tasks as the social stressors, which may limit generalizability to real-world cannabis use situations given that fears of social situations involving social interactions (e.g. attending parties, talking with unfamiliar people) are more indicative of greater social anxiety (Crome and Baillie, 2014). The only known study to use a social interaction task (Buckner et al., 2013) did not report whether the relationship between cannabis craving and state social anxiety varied as a function of SAD status. Fourth, it is unclear whether those with a CUD are especially vulnerable to wanting to use cannabis during periods of elevated state social anxiety. Fifth, extant work (Buckner et al., 2011; Buckner et al., 2013) has been completed with primarily Caucasian samples, limiting generalizability to more racially diverse individuals. This limitation is unfortunate, as cannabis-related problems are often overrepresented in racially diverse populations (e.g. Wu et al., 2014).

The present study set out to address clinically and theoretically-significant gaps in the literature in several ways. First, we sought to extend prior work (Buckner et al., 2013) finding that compared to those in a socially neutral (reading) condition, participants in an anxiety-provoking social interaction condition would report greater state social anxiety and greater cannabis craving by testing whether those in the social interaction task with the greatest physiological arousal would demonstrate the greatest craving. Second, we tested whether coping motives were the most common reasons cited for wanting to use cannabis. Third, we tested whether SAD status moderated the relationship between condition and craving such that those with SAD in the social interaction condition would evince the greatest cannabis craving. Fourth, to test the specificity of the SAD moderation, we test whether CUD status would also moderate the relation between condition and craving. Fifth, these hypotheses were tested in a racially diverse sample.

Method

Participants

Participants were recruited via community advertisements (e.g. newspaper and on-line ads, flyers posted in local laundromats, coffee shops, bars, etc.) for a study on the relationship between cannabis and anxiety from May 2011 to February 2014. Interested participants completed a screening (on-line or telephone) and baseline appointment to determine eligibility. Eligibility criteria included being between 18 and 45 years old, past-month

cannabis use (confirmed via urine sample using a 50 ng/mL positive cutoff, which detects cannabis use up to 78 hours post-ingestion), cannabis as drug of choice, and no interest in, or current receipt of, substance use disorder treatment. Participants were asked not to use cannabis on the day of their appointment. Of the 144 who attended an appointment, 17 were excluded because they: denied current cannabis use during the clinical interview ($n = 1$), reported using cannabis the day of the appointment ($n = 1$), reported a history of hallucinations or delusions ($n = 4$) given the negative reactions experienced by individuals with these symptoms upon using cannabis (Barkus and Lewis, 2008; Barkus et al., 2006; Stirling et al., 2008), met criteria for a psychiatric problem that contraindicated participation (e.g. primary illicit substance dependence other than cannabis, likely organic brain disorder; $n = 4$), reported that cannabis was not their drug of choice ($n = 2$), and provided urine samples that were negative for THC ($n = 5$). One participant dropped out of the study during the clinical interview.

The final sample consisted of 126 current cannabis users aged 18–36. Nearly all (95.2%) endorsed past-month alcohol use and 78.6% reported lifetime tobacco use (26.2% endorsed past-week smoking). The ethnic/racial composition was 28.6% African American, 3.2% Asian, 54.0% non-Hispanic Caucasian, 2.4% Hispanic Caucasian, 8.7% “mixed”, and 3.2% other. The majority met DSM-IV-TR (American Psychiatric Association, 2000) criteria for a current CUD (17.5% cannabis abuse, 71.4% cannabis dependence). Additional descriptive information appears in Table 1.

Measures

Baseline assessments—Diagnostic status was determined via clinical interview using the *Structured Clinical Interview for DSM-IV Disorders* (Patient Edition, with psychotic screening module; SCID-I/P [w/ Psychotic Screen]; First et al., 2007). Original ratings were compared to ratings of random sample of 20% of the recordings made by trained graduate students blind to initial diagnostic status. Percent agreement between the two raters for primary CUD diagnosis was 92.3%. Past 90-day cannabis use frequency was assessed with the *Timeline FollowBack* (TLFB; Sobell and Sobell, 1996) for cannabis. To insure that the two conditions did not differ at baseline on trait anxiety, cannabis craving, or cannabis use motives, trait anxiety was assessed with the anxiety subscale of the *Brief Symptom Inventory* (BSI; Derogatis and Melisaratos, 1983), a self-report measure of psychiatric symptomatology. Items were rated on Likert-like scales from 1 to 4, with greater scores reflecting greater symptom severity. The anxiety subscale demonstrated good internal consistency in the current sample ($\alpha = .86$). Baseline cannabis craving was assessed with the 12-item version of the *Marijuana Craving Questionnaire* (MCQ; Heishman et al., 2009). Participants used a Likert-type scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The MCQ demonstrated good internal consistency in the current sample ($\alpha = .87$). The *Marijuana Motives Measure* (MMM; Simons et al., 1998) is a 25-item measure assessing the following cannabis use motives: enhancement (e.g. to get high), coping (e.g. to forget my worries), social (e.g. to enjoy a party), conformity (e.g. to fit in with a group I like), and expansion (e.g. to expand my awareness). Participants indicate on a 1 (*almost never/never*) to 5 (*almost always/always*) scale the degree to which they have smoked cannabis for particular reasons. MMM subscales have demonstrated adequate internal consistency in

prior work (Chabrol et al., 2005), with alphas in the current sample as follows: expansion $\alpha = .94$, social $\alpha = .88$, coping $\alpha = .86$, conformity $\alpha = .68$, and enhancement $\alpha = .57$.

Task assessments—Assessment measures were designed to be brief so as to avoid inadvertently decreasing state anxiety by distracting participants from the task for a long period of time. Cannabis craving during the task was rated on an 11-point (0 to 10) visual analog scale (VAS) that correlates with longer measures of cannabis craving (e.g. Buckner et al., 2011). State anxiety was assessed at baseline and throughout the task using *Subjective Units of Discomfort* (SUDS; Wolpe, 1968), a commonly used, brief, validated measure of state anxiety during anxiety-induction tasks (see Chorpita and Taylor, 2001), for which participants rate their state anxiety from 0 (*totally relaxed, on the verge of sleep*) to 10 (*the highest anxiety you have ever experienced*). Cannabis use motives were assessed by asking participants to write their reasons for wanting to use cannabis or not wanting to use cannabis at each assessment point during the task. These motives were classified by two raters. A two-way mixed-effects model intraclass correlation coefficient (ICC) for absolute agreement was examined and inter-rater reliability was excellent (average ICC = .93, 95% C.I. = .89-.95).

Heart rate and skin conductance were measured as psychophysiological indicators of state anxiety during the task (e.g. Croft et al., 2004). Physiological measures were obtained using Coulbourn Instruments LabLinc system with ECG electrodes attached directly to the skin. Two electrodes were placed on each wrist to measure heart rate and two were placed on the palm of the non-dominant hand to measure skin conductance. A fifth electrode was placed on the ankle as a ground electrode. Samples were obtained at a rate of 400 samples per second. Average heart rate and skin conductance was calculated for the baseline period, anticipatory period, and during the task.

Experimental conditions

Social interaction task—The procedure for this task was based on adaptations of the Borkovec Social Anxiety induction procedure (Borkovec et al., 1974) made by Abrams and Wilson (1979) and de Boer et al. (1993). Via recorded instructions, participants were asked to relax and imagine a calm, pleasant scene. They were then instructed to speak to a confederate and to make as favorable an impression as possible on the confederate. They were instructed that the confederate was a research assistant who was trained to listen attentively but to not talk. The confederate then entered the room and the participant was instructed to begin the interaction. Participants spoke for three minutes. To further increase anxiety, participants were told that the interaction was video recorded. This task has been successfully used to manipulate state social anxiety among substance users (e.g. Abrams and Wilson, 1979; de Boer et al., 1993; Keane and Lisman, 1980; Niaura et al., 2002) including cannabis users (Buckner et al., 2013).

Reading task—A reading task was used as the control procedure. Participants in this condition were told that their task was to silently read a *Popular Mechanics* magazine at their own pace. As in the Social Interaction Task, participants were told they were being video recorded during the task. Via recorded instructions, participants were instructed when

to begin reading as well as when to complete assessments of state craving and anxiety. Participants read for three minutes. Reading tasks have been shown to produce significantly less anxiety than social anxiety challenges among cannabis users (Buckner et al., 2011).

Confederate training and adherence

Confederates were graduate and undergraduate students who were trained to keep a neutral yet interested facial expression (de Boer et al., 1993). If a participant asked questions, confederates responded “Please stick to the instructions”. If the participant was silent for more than five seconds, the confederate asked either “Do you have any hobbies?” or “Is there anything you are specifically interested in?” A random selection of 30% of task recordings was rated for adherence from 0 (*not at all neutral/interested*) to 7 (*very neutral/very interested*). Mean neutrality and interest were high: 6.84 ($SD = 0.38$) and 6.15 ($SD = 0.89$) respectively.

Procedure

Study procedures were approved by the university’s Institutional Review Board. On the day of the appointment, the participant met individually with a trained clinical interviewer. Given that in vivo cues increase marijuana craving (Gray et al., 2008), the study took place in a simulated living room that contained visual marijuana cues (i.e. ashtray, lighter, glass handheld pipe, water pipe). Prior to data collection, informed consent was obtained. Participants were randomly assigned to one of the two conditions using an urn randomization program to ensure equal distribution of relevant variables (i.e. cannabis use frequency, employment, race, gender, SAD diagnostic status) between conditions: social interaction task ($n = 60$) and reading task ($n = 66$). Participants were then connected to the psychophysiological equipment and instructed to move as little as possible throughout the task. Cannabis craving VAS scales, SUD ratings, and cannabis use motives assessments were completed three times: immediately prior to task initiation (after being informed of condition assignment; Time 1), 90 seconds into the task (Time 2), and immediately after the task (Time 3). Participants were then debriefed, compensated \$50 for their time, and provided referrals for local mental health and substance abuse treatment facilities.

Data analytic strategy

To ensure conditions did not differ at baseline on demographic and other relevant variables, one-way analyses of variance (ANOVAs) were conducted for continuous variables and χ^2 analyses were performed for dichotomous variables. To evaluate the success of the experimental manipulation of state anxiety (measured via SUDS), a 3 (Time: Times 1–3) $\times$ 2 (Condition: Reading vs. Social Interaction) repeated measures analysis of covariance (ANCOVA) was conducted. Baseline BSI-anxiety was included as a covariate.¹ To examine whether conditions differed on cannabis craving ratings over time, a 3 (Time: Times 1–3) $\times$ 2 (Condition) repeated measures ANCOVA was conducted with cannabis use frequency and gender as covariates.¹ Given that the relationship between condition and cannabis craving did not vary as a function of time (see Results section), cannabis craving ratings across the

¹A similar pattern of results was obtained when models were analyzed without covariates.

three time points were averaged and ANOVA was used to test whether the following interactions predicted cannabis craving: heart rate $\times$ condition, skin conductance $\times$ condition, SAD status $\times$ condition, and CUD status $\times$ condition. We also tested the impact of race by examining the race $\times$ condition and race $\times$ SAD status $\times$ condition interactions. Given that African American and non-Hispanic Caucasian races were the most prevalent races in the current dataset, race was dummy coded (1 = African American, 0 = non-Hispanic Caucasian). Past-month cannabis use frequency and gender were included as covariates.

Results

Sample characteristics

The conditions did not differ on SAD or CUD diagnostic status, anxiety or substance use disorder treatment history, frequency of cannabis use, cannabis-related problems, or demographic variables (Table 1). Importantly, conditions also did not differ on baseline anxiety or cannabis craving.

Manipulation check

The 3 (Time) $\times$ 2 (Condition) interaction was significant, $F(1.78, 207.62) = 11.69, p < .001, \omega^2 = .02$ (Figure 1). Compared to reading participants, participants in the social interaction condition reported significantly greater anxiety before ($F(1, 117) = 18.93, p < .001, 95\% \text{ CI of difference: } 0.77, 2.01$), during ($F(1, 117) = 48.90, p < .001, 95\% \text{ CI of difference: } 2.08, 3.73$), and after ($F(1, 117) = 23.32, p < .001, 95\% \text{ CI of difference: } 1.21, 2.89$) the task.

Effects of social stressor on cannabis craving

The 3 (Time) $\times$ 2 (Condition) interaction was not significant, $F(2, 232) = 1.94, p = .145, \omega^2 = .00$. There was, however, a significant between-subjects effect, $F(1, 116) = 5.15, p = .025, \omega^2 = .03$, such that compared to the reading condition, the social interaction condition reported greater craving during ($M = 5.14, SE = .43$ vs. $M = 3.62, SE = .40$; $F(1, 116) = 6.59, p = .012, 95\% \text{ CI of difference: } 0.35, 2.68$) and after ($M = 5.25, SE = .43$ vs. $M = 4.1, SE = .39$; $F(1, 116) = 3.94, p = .049, 95\% \text{ CI of difference: } 0.003, 2.303$) the task. Before the task, the social interaction condition reported non-significantly greater craving ($M = 4.06, SE = .37$ vs. $M = 3.08, SE = .34$; $F(1, 116) = 3.80, p = .054, 95\% \text{ CI of difference: } -0.02, 1.98$).

Neither heart rate, $F(1, 73) = 0.16, p = .691, \eta^2 = .00$, nor skin conductance, $F(1, 73) = 0.81, p = .370, \eta^2 = .01$, moderated the relationship of experimental condition and mean cannabis craving.

Effects of social stressor on craving by social anxiety disorder status

Table 1 presents % of participants with SAD per condition. SAD+ participants in the social interaction condition reported a mean craving of 6.59 ($SD = 3.42$), SAD+ participants in the control condition reported a mean craving of 3.69 ($SD = 2.73$), SAD- participants in the social interaction condition reported a mean craving of 4.61 ($SD = 3.32$), and SAD- participants in the control condition reported a mean craving of 3.91 ($SD = 3.25$). The SAD

status $\times$ condition interaction significantly predicted mean cannabis craving, $F(1, 114) = 4.74$, $p = .032$, $\eta^2 = .03$.² The regression lines are graphed in Figure 2. To probe the nature of the significant interaction, tests of simple slopes were also conducted as recommended by Aiken and West (1991). The simple slope was significant for SAD+ participants, $\beta = 2.32$, $p = .022$. This was not the case for SAD– participants, $\beta = 0.23$, $p = .232$. We also tested whether the simple slope of the social interaction condition and of the control condition differed from zero. Among participants in the social interaction condition, SAD+ participants reported significantly greater craving than SAD– participants, $\beta = 1.98$, $p = .030$. In the control condition, SAD+ participants did not report significantly greater craving than SAD– participants, $\beta = -0.66$, $p = .421$. This pattern of findings suggests that the social interaction task was associated with significantly more craving for SAD+, but not SAD–, participants.

Effects of social stressor on craving by cannabis use disorder status and race

The CUD status $\times$ condition interaction did not significantly predict cannabis craving, $F(1, 119) = 0.00$, $p = .962$, $\eta^2 = .00$. The race $\times$ condition interaction also did not predict cannabis craving, $F(1, 99) = 1.07$, $p = .303$, $\eta^2 = .01$. Similarly, the race $\times$ SAD status $\times$ Condition interaction was not significant, $F(1, 90) = 0.68$, $p = .412$, $\eta^2 = .01$.

Cannabis use motives

Among those in the social interaction condition, coping (e.g. decrease anxiety/nervousness, calm down) motives were the most common reasons cited (54.1%) during the task, followed by enhancement motives (e.g. it is pleasurable, “I like to be high”; 18.9%), social (e.g. this conversation would be more fun; 10.8%), cue reactivity (e.g. pipe and bong in room, it is being talked about; 5.4%), and other motives (e.g. not having done it yet today, headache, “just because”; 10.8). Among those in the reading condition, coping (27.5%) and boredom (27.5%) were the most common motives, followed by enhancement motives (25.0%), cue reactivity (2.5%) and social (2.5%) and expansion motives (2.5%), with 12.5% endorsing other reasons. Participants in the social interaction condition reported significantly more coping motives during the task than those in the reading condition, $\chi^2(1, 77) = 5.64$, $p = .018$, Cramer’s $V = .271$.

Discussion

Findings from this experimental study contribute to our understanding of the relation between social anxiety (both elevated state social anxiety and elevated trait social anxiety or SAD) and cannabis use vulnerability factors in several novel and significant ways. Somewhat consistent with the finding that CDB did not impact heart rate or skin conductance during a speech task among healthy (i.e. non-drug using) participants (Zuardi et al., 1993), we found that physiological arousal did not moderate the relationship between condition and cannabis craving among our sample of current cannabis users. Findings also extend prior studies of laboratory-induced state social anxiety among current cannabis users (Buckner et al., 2011; Buckner et al., 2013) in at least five key ways.

²Gender did not significantly moderate this relationship, $F(1, 111) = 0.50$, $p = .480$.

First, this is the first known study to assess whether cannabis use motives are proximally related to desire to use cannabis during periods of elevated state social anxiety. Although the social interaction task elicited anxiety rates that were, on average, 4.5/10, lower ratings of anxiety (2.4) predicted cannabis use in an ecological momentary assessment of predictors of cannabis use (Buckner et al., 2012a). Future work is necessary to test whether the levels of anxiety experienced during real-world social-anxiety provoking situations is associated with greater craving. Despite the lack of impact of physiological arousal, coping motives were the most common reasons cited for wanting to use cannabis, suggesting that current cannabis users are vulnerable to wanting to use cannabis to manage their subjective experience of negative affect, such as state social anxiety. In line with tension-reduction based models of use (Conger, 1956), coping motives were reported more often among participants in the social anxiety-induction task than in the control task, indicating that cannabis users are more vulnerable to use during times of elevated state social anxiety. Our finding that coping and enhancement motives were among the most commonly cited motives in both conditions is consistent with prior work finding these motives to be the most commonly cited reasons for in vivo cannabis use (Buckner et al., 2015).

Second, the current study replicated prior work (Buckner et al., 2011) finding that increases in state social anxiety during a speech task are especially related to cannabis craving among those with SAD. Specifically, although the significant difference between conditions on cannabis craving was somewhat small in magnitude among all participants, those with SAD in the social interaction condition reported a “marked urge” to use cannabis on average whereas SAD— participants in the reading condition reported a “moderate urge”. We extended this work by observing that SAD moderated the relation between condition and cannabis craving during a social interaction task, thereby increasing ecological validity given that social situations involving interactions are among the more feared situations of individuals with more severe social anxiety (Crome and Baillie, 2014). Additionally, we found that SAD moderated this relation to predict craving throughout the task, whereas the 2011 study found this to be the case only during (i.e. half-way through) the task. This finding supports the contention that choice of task is important when examining the impact of social anxiety on drug use behaviors. Third, to test the specificity of the SAD moderation, we tested whether CUD status also moderated the relation between condition and craving. The lack of moderational impact of CUD status suggests that severity of psychopathology generally did not interact with condition to predict craving; rather, the effect was specific to SAD. However, given the small percentage of participants without CUD, replication with larger samples of non-disordered cannabis users is necessary.

Fourth, prior studies were conducted with samples that were primarily Caucasian and little research has identified factors related to cannabis use vulnerability factors among more racially diverse samples. It is important to note, however, that although the sample was relatively racially diverse, the small n’s per racial/ethnic category preclude our ability to test whether some racial groups were more or less likely to want to use cannabis in response to social stress. Future work could benefit from testing the impact of race on these relationships.

This study should be considered in light of limitations that point to additional avenues of work in this area. First, cannabis craving, not use, was examined. Although craving has been found to be strongly related to cannabis use (e.g. Buckner et al., 2012a), future work would benefit from examination of whether observed relationships hold true for actual cannabis use. Second, the control task did not control for negative affect broadly and it appears to have induced boredom in at least some participants given that many participants in the control condition reported wanting to use cannabis to alleviate boredom. Third, we did not biologically verify cannabis abstinence on day of appointment and future research could benefit from controlling for time of last use such that all participants are in a similar state of cannabis withdrawal during the anxiety-induction task. Relatedly, we did not test whether conditions differed on cannabis withdrawal. Although they did not differ on baseline cannabis craving (the most common symptom of withdrawal; see Budney et al., 2004), future work may consider controlling for withdrawal. Fourth, future work could benefit from use of an established measure of cannabis use motives (e.g. Comprehensive Marijuana Motive Questionnaire; Lee et al., 2009). Fifth, the sample evinced high rates of other substance use (e.g. alcohol) and psychiatric disorders, which may increase generalizability to cannabis users with CUD (given the majority of our sample met DSM-IV criteria for a CUD) given high rates of other substance use and comorbidity among individuals with CUD (Stinson et al., 2006). However, future work could benefit from more controlled studies of cannabis users without these co-occurring conditions. Sixth, the sample was comprised of non-treatment-seeking cannabis users recruited from the community. This sampling strategy was chosen given that the majority of cannabis users with a CUD do not seek treatment (Stinson et al., 2006). Yet, testing whether observed relations generalize to cannabis users in CUD treatment will be an important next step. Seventh, we did not assess for use of psychotropic medications and future work considering use of such medications will be an important step in this line of research. Eighth, the urinalysis employed in the current study to confirm current cannabis use detected use up to 78 hours post-ingestion. Although only five potential participants were excluded based on the results of this test, future work that includes more infrequent cannabis users could be useful to determine whether results generalize to more diverse patterns of use.

Overall, the present study provides important experimental evidence suggesting that social interaction anxiety appears to increase desire to use cannabis among current cannabis users and that this is especially true among those with SAD. Therefore, interventions may benefit by targeting social anxiety and SAD in the management of CUD.

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Figure 1. The interaction of time and condition in the prediction of state anxiety, controlling for baseline anxiety.

Figure 2.

Interaction of social anxiety disorder (SAD) status with condition in the prediction of cannabis craving during the experimental task.

*Slope is significantly different from zero, $p < .05$.

Table 1

Demographic characteristics of randomized sample for total sample by experimental condition.

Dependent variable	Task			<i>F</i> or χ^2	<i>p</i>	<i>d</i> or Cramer's <i>V</i>
	Total (<i>n</i> = 123)	Reading (<i>n</i> = 66)	Social interaction (<i>n</i> = 60)			
Age (years)	21.2 (3.3)	21.0 (3.2)	21.4 (3.4)	0.43	.513	.119
Gender (% male)	65.6	60.6	71.2	1.55	.214	.111
Race (% Caucasian)	56.8	59.1	54.2	2.17	.704	.132
Ethnicity (% non-Hispanic/Latino)	91.2	87.9	94.9	1.92	.166	.124
Employed (%)	60.2	57.6	63.2	0.40	.528	.057
Anxiety treatment history (%)	18.4	19.7	16.9	0.16	.692	.035
Substance use disorder treatment history (%)	9.6	7.6	11.9	0.66	.416	.073
Cannabis use disorder (%)	88.3	88.1	88.5	0.01	.935	.007
Past-month cannabis use (# days)	21.7 (9.0)	21.1 (9.4)	22.3 (8.6)	0.50	.482	.125
Cannabis problems	5.3 (3.6)	5.3 (3.3)	5.3 (3.9)	0.00	.993	.002
Age of first cannabis use	16.2 (2.1)	16.5 (2.0)	16.0 (2.2)	1.71	.193	.231
Social anxiety disorder (%)	31.7	31.8	31.7	0.00	.985	.002
Alcohol use disorder	32.5	16.7	15.9	0.03	.856	.016
Other (non-cannabis) illicit substance use disorder	6.3	3.2	3.2	0.02	.889	.012
Baseline anxiety	0.8	0.9 (.7)	0.8 (.7)	0.61	.437	.130
Baseline cannabis craving	49.4 (14.0)	48.9 (14.1)	49.8 (14.0)	0.13	.717	.065

Chi-square and ANOVA analyses were conducted to determine whether experimental conditions differed. Numbers presented are means and standard deviations for the total sample and each condition unless noted otherwise. Baseline anxiety was assessed via the *Brief Symptom Inventory* (BSI; Derogatis and Melisaratos, 1983) and baseline cannabis craving was assessed with the short form of the *Marijuana Craving Questionnaire* (MCQ; Heishman et al., 2009).