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Mallory Loflin

University at Albany, State University of New York, mloflin@albany.edu

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Outcome Expectancies Mediate the Impact of Olfactory Cues on Marijuana Craving

by

Mallory Loflin

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Abstract

Current work suggests that the presence of “craving” may be a significant indicator of problematic substance use. Nevertheless, little work has examined how cannabis users experience and develop craving. Most relevant studies focus on samples in treatment. Previous work suggests that cues for marijuana might activate outcome expectancies that contribute to the development of craving. The present study sought to test whether an olfactory marijuana cue would create changes in expectancy, mood, and craving in a non-treatment seeking sample representing both users and non-users. Unlike control cues, olfactory cues for marijuana increased perceptions of the likelihood of marijuana-induced positive outcomes and self-reported craving in both users and non-users. Future work is necessary to identify who among those who report “craving” go on to develop problems, and to determine whether changes in craving are indicative of problematic use of cannabis.

Keywords: Craving, marijuana, college-age substance use, cue-reactance
Outcome expectancies mediate the impact of olfactory cues on marijuana craving

Background

Cannabis dependence is the second most frequently cited reason for college students to enter treatment for substance abuse (Arria et al., 2008). Meanwhile, marijuana is also the most widely used illicit substance of abuse within this population; nearly one half of college students report using marijuana in their lifetime, with one third reporting past year use (Johnston, O’Malley, Bachman, & Schulenberg, 2012). Use itself of marijuana among young adults is largely normative. Therefore, work that identifies correlates of problematic use is necessary.

Current research focuses on craving and its role in the development of problematic use and dependency (Goldstein & Volkow, 2002). The presence of craving in the drug user, defined by a sense of urgency surrounding the acute desire to take the substance (Kozolowski & Wilkinson, 1987), potentially signifies problematic use. Since 1955, when a World Health Organization (WHO) panel determined that craving was the basis of the onset of addiction (Jellinek et al., 1955), craving has appeared as one of the diagnostic criteria for substance related disorders in the ICD-10. Yet, it does not appear in the Diagnostics and Statistical Manual for Mental Disorders (DSM-IV-TR) for any of the substance use disorders. In May of 2013, however, the American Psychiatric Association (APA) will release its latest edition of the Diagnostics and Statistical Manual for Mental Disorders (DSM-5). The DSM task force responsible for the revisions of the manual proposed changes to the diagnostic criteria for all substance use disorders, including cannabis use disorder and cannabis dependency disorder (Casteel & Valora,
These changes would include the addition of craving as a criterion for diagnosis. Nevertheless, support for this link between craving and dependence arises primarily from work on alcohol (Cherpitel et al., 2010; de Bruijn, van den Brink, de Graaf, & Vollebergh, 2005; Keyes, Krueger, Grant, & Hasin, 2010). Experiments linking craving to problems in cannabis users are limited. To date, research has been inconclusive as to whether the experience of cannabis craving is indicative of problems related to use that would signify “disorder.” The few papers that support craving’s role in problematic marijuana use focus on treatment-seeking individuals (Budney, Novy, & Hughes, 1999). These studies often fail to sample from the full breadth of users who both do and do not exhibit problems related to use. No experimental work has examined cannabis craving using a college-age sample. Because marijuana use is largely normative among college students, this age group includes many who use at a high frequency but may or may not report problems. An understanding of how the full array of cannabis users experience states of craving is necessary to understand the function of craving in the development of problematic use, and ultimately identify potential targets amenable for intervention.

**Craving Development and Function**

Several models attempt to address the role of craving in drug problems (for a review see Drummond, 2001). The majority of these models are based on basic tenants of classical conditioning and learning theory, where “craving” is seen to develop as a function of continuous exposure to- and reinforcement of- the drug’s effects. Cognitive components of craving, such as expectancy, can also be explained through the same process. As stimuli related to the drug are repeatedly paired with use of the drug, the stimuli, or cues, become associated with the drug itself. Likewise, the effects, or
outcome, of the substance will also become associated with the drug and, therefore, the
drug-related stimuli. Activation of such beliefs about the effects of the drug can then
drive motivation for use in the future, potentially indicative of a state of craving. If this
conditioning process has occurred, we expect to see both the activation of beliefs about
the effects of the drug as well as an increase in self-reported craving after the presentation
of relevant cues. These types of cue-reactance based outcome-expectancy models
appear frequently in the literature (Christiansen & Smith, 1991; Rather & Goldman,
1994; Rather, Goldman, Roehrich, & Brannick, 1992).

In addition to the role of expectancy in craving, drug-specific outcome memories
often become associated with accompanying mood states as a reflection of the positively
reinforcing component of VTA dopamine release by the drug (Robinson & Berridge,
2003). Moreover, increases in dopamine are strongly linked to increases in acute
attention (Schultz, Dayan, & Montague, 1997). This association suggests that when
deso-limbic regions of the brain associated with reward are activated through
dopaminergic pathways, then attention to drug stimuli should become even more salient.

Increased attention narrows the proximal distance between a given stimulus (cue) and
response (positive mood). Therefore, we should also expect to see increases in positive
mood-based memory after cue presentation, in addition to expectancy changes, if craving
has occurred. Sensory activation, predominantly regarding scented cues, may be
particularly of note with marijuana craving, because olfactory stimulation is implicated in
the development of emotional memory (Herz, Eliassen, Beland, & Souza, 2004). This
link between scent and affect would suggest that the unique aroma of marijuana might
play an interesting role in the development of these expectancy-memory networks that purportedly relate to the development of craving.

**Craving and Cue-Reactivity**

Support for outcome-expectancy models of craving comes from research in cue-reactance, where physiological states associated with craving, such as skin conductance, heart-rate, and salivation (Geier, Mucha, & Pauli, 2000; Kaplan et al., 1985) change as reported expectancies about the substance’s effects, mood, and interest in using the drug shift in the presence of a drug cue (Carter & Tiffany, 1999; Monti, Rohsenow, & Hutchison, 2000). Word association tasks reveal that drug-related cues enhance implicit drug- or expectancy-related memories (Ames & Stacy, 1998; Nelson, McEvoy, & Dennis, 2000). Notably, previous work suggests that problematic users are more likely to endorse positive expectancies and downgrade the likelihood of negative outcomes following the presentation of associated cues; an effect that we do not see in novice users (Niaura et al., 1988). Nevertheless, some studies using cue-reactance paradigms have shown increases in likelihood ratings after cue presentation for both positive and negative outcomes (Baker, Morse, & Sherman, 1987). Both effects have been studied primarily with alcohol and nicotine users.

While counter-intuitive, the finding of an association between reporting an increased saliency of negative outcome-expectancies and craving might be an artifact of the type of craving that the user is reporting. Drummond (2001) points to the distinction between craving in response to cues (i.e., cue-reactance elicited) and craving in response to a withdrawal state (i.e., withdrawal related craving). Craving in response to withdrawal likely develops as a negatively reinforced reaction to seek out use of the drug...
to alleviate negative mood states. The discomfort of withdrawal might function as a contextual cue to induce craving. This form of craving then would likewise become associated with secondary reactions to the drug’s acute effects, such as the affective states associated with withdrawal. Hence, we can see how both positive and negative affective states and changes in both positive and negative outcome-expectancies can facilitate craving when withdrawal is present. Dual-affect models of craving are based on this premise (Baker, Morse, & Sherman, 1987). Nevertheless, among non-treatment seeking users who are less likely to show indication of dependency we would not expect to see indications of withdrawal-induced craving. For these users we would not expect to see decreases in mood or increases in saliency of negative outcomes following cue-presentation.

**Applications of Cue-Reactivity**

The cue-reactivity paradigm, where individuals are exposed to cues relevant to the substance, provides a useful means of studying craving and it’s correlated phenomena (Carter & Tiffany, 1999). Moreover, when applied to specific substances, the model can also provide information for the development of psychological interventions, as we see from the alcohol and nicotine literature. For example, early experimentation using cue-reactance paradigms with cigarette smokers found that the presentation of nicotine cues using imagery scripts elicited an increase in self-reported craving, as well as increases in heart rate and galvanic skin-response, and decreases in reaction time responses (Cepeda-Benito & Tiffany, 1996). What followed from this research was the development of interventions that reduce reactivity to nicotine related cues. For example, trials of coping skill techniques for nicotine related cravings, such as urge-surfing, have shown efficacy
in reducing individuals’ reactivity to smoking related cues that previously induced cigarette craving (Bowen & Marlatt, 2009). Likewise, numerous studies have used the presentation of alcohol as a cue to test craving and reactivity among dependent alcoholics (for review see Carter & Tiffany, 1999). In each of the reviewed studies the presentation of alcohol as the cue resulted in increases in craving, heart rate, skin temperature, and sweat gland activity. This literature, which supports a connection between alcohol related cue-reactance and craving, has also influenced the development of crave management interventions that function by reducing cue-reactivity (e.g., Rohsenow et al., 2002).

**Craving, Cues, and Cannabis**

Within the cannabis literature, cue-reactivity manipulations remain limited; most studies relying on visual cues. Nickerson et al. (2011) looked at cue-reactance of cannabis by showing pictures of marijuana to cannabis-dependent adolescents and asking them to handle paraphernalia used to smoke the plant. They found that those who were presented with the cues reported higher craving for marijuana than those who were not. Comparable results appear in other studies that employ primarily visual cues (e.g., Lundahl & Johanson, 2011; Wolfling, Flor, & Grusser, 2008). Wolfling et al.’s (2008) study was specifically interested in whether physiological responses to visual material associated with cannabis (i.e. pictures of marijuana) would differ among heavy long-term cannabis users and healthy matched controls. Again, the results showed that visual cues increased reported craving, but also found that the cues increased arousal, specifically skin-conductance, only among the cannabis users. This result relating cues to arousal did not replicate in another experiment that found increased craving in response to cues
(Lundahl & Johanson, 2011). However, this study may have been underpowered to find such effects (N=32), given that effect sizes of this type are typically small, ranging from .24 to .26 (Carter & Tiffany, 1999). While marijuana-associated pictures and objects consistently create craving, they apparently do not always lead to heightened physiological reactions. Furthermore, all three studies focused on heavy chronic users and those who met criteria for cannabis dependence rather than participants with a broader range of use. Moreover, limitations also existed with using pictures and paraphernalia as cues. Many participants might not use the type of ingestion mechanism presented (e.g., pipes, water pipes, etc.), and photographs might not generalize well to real world environmental stimuli.

Recent work has focused on adding more cues to create cannabis craving, including virtual reality. One such manipulation tested cannabis cue-reactance by use of four virtual reality (VR) simulations containing audio, visual, olfactory, and vibro-tactile sensory stimuli among non-treatment seeking cannabis users (Bordnick et al., 2009). In this design, participants were exposed to two experimental VR environments with cues consistent with a “party room” of people smoking marijuana and a room containing paraphernalia, and two neutral rooms. The results of the study showed that craving and attention to the cannabis related cues was higher in the two experimental environments. The major limitation of this study was, again, its utilization of over-generalized and stereotyped stimuli, in this instance a room of other people smoking joints and bongs with new age music playing. One other manipulation used a visualization technique and found that adult participants self-reported more craving to marijuana in response to auditory imagery scripts (Singleton, Trotman, Zavahir, Taylor, & Heishman, 2002). This
finding was corroborated in a study using young adults with cannabis use disorder that utilized a similar imagery script design (Gray, LaRowe, & Upadhyaya, 2008). While both studies’ results were successful in inducing craving for dependent users, the use of imagery scripts relies again on an assumption of specific environments and sets associated with the use of cannabis, rather than the cue of the drug itself. Furthermore, all reviewed studies looked at cued craving only among dependent users or dependent users versus controls.

**Aims**

The focus of the current study was to explore whether an olfactory cue activates proposed networks of marijuana craving in a non-treatment seeking sample that includes both cannabis users and non-users. The current paper had three specific hypotheses:

1. Exposure to the olfactory cue would predict increases in mood, increases in positive expectancy, decreases in negative expectancy, and increases in craving.

2. Significant associations outlined in hypothesis 1 would be dependent on history of marijuana use; an interaction would be present between past 90 day marijuana use and condition.

3. Significant associations between olfactory cue and mood, positive expectancy, and negative expectancy would partially mediate the association between cue and craving.
Method

Participants

Participants were recruited through the University at Albany psychology subject pool and were given course credit in exchange for their participation.

Selection of the current sample. Participants were excluded if they were under the age of 18 or were not proficient in English.

Demographics of the current sample. Participant demographics appear in Table 1.

Materials

The current study used the same experimental stimulus and procedures as outlined in Loflin and Earleywine (under review). The scent for the aroma cue used a cannabis sativa essential oil. The cue contains no active Δ9-tetrahydrocannabinol (Δ9-THC), the psychoactive compound found in marijuana. Mugwort was chosen to encase the oil for its similar density and mild plant-based aroma.

Plastic cups with lids containing small holes were used to house the experimental stimulus. Standard cotton balls were used in place of the mugwort/cannabis oil for the cups used in the control condition.

Procedure

Participants were randomly assigned by group session time to either the experimental or control condition. After being consented by the research assistant, participants were seated at an enclosed desk with a computer containing the survey, Time Line Follow-Back sheet (TLFB), and a lidded cup that contained the relevant stimulus. As participants completed their survey intermittent prompts instructed them to raise the
cup to their nose and smell its contents prior to each questionnaire. Nothing in the
recruitment flyer or informed consent form explicitly mentioned marijuana, to reduce the
risk of participants being inadvertently cued. After completion of the survey, participants
were able to shred their own TLFB sheet and were provided debriefing forms. All study
protocols, materials, and informed consent were approved by a local Institutional Review
Board.

**Measures.** The measures used in the current study included questionnaires
regarding participants’ history of marijuana use, current use of marijuana, mood after cue
presentation, expectancies regarding marijuana’s effects, and subjective craving.

**Marijuana use.** All participants were asked if they had ever used marijuana in
their lifetime, and if so, if they had used marijuana in the past 90 days. If a participant
reported using marijuana in the past 90 days, then quantity and frequency of self-reported
marijuana use was assessed using a Time-Line Follow Back (TLFB) instrument (Duhig,
Cavallo, McKee, George, & Krishnan-Srin, 2005; Sobell & Sobell, 1992). Participants
were asked to provide information on events such as parties, holidays, school exams,
visits from friends, etc. This information was intended to be entered into the TLFB
calendar and used to enhance recall of marijuana use over the past 90 days. Density of
use was then assessed by asking how many joints/bowls/cones of cannabis were
consumed over the past 90 days. Two-hundred and fifty-nine participants reported
lifetime use (73.6%), and 170 participants reported using marijuana over the past 90 days
(48.3%). Self-reported use ranged between 0-90 ($M = 14.02$, $SD = 27.24$).

**Marijuana craving.** Current craving of marijuana was assessed using a single
item measure (Nickerson et al., 2011). Participants were asked to rate from 0 ‘no desire
at all’ to 5 ‘very strong desire,’ “How strong is your desire to smoke marijuana right now?” Raw score craving ratings ranged between 1-5 ($M = 1.78$, $SD = 1.09$).

**Marijuana expectancy.** Expectancies were measured using an adaptation of the BCEOA (Ham et al., 2005), modified for marijuana using 22 statements generated from other work on common perceptions of marijuana use (Connor, Gullo, Feeney, & Young, 2011; Linkovich-Kyle & Dunn, 2001). Participants were asked first to rate how likely each outcome would be if they were using marijuana on a scale from -2 ‘disagree’ to 2 ‘agree.’ They were then asked to rate how good or bad each particular effect would be if it were to happen, regardless of whether they expect it to happen or not, on a scale from -2 ‘bad’ to 2 ‘good.’ Positive expectancy scores were calculated by summing each participant’s likelihood rankings of all scores that averaged above zero for the entire sample on bad/good rankings of items. Negative expectancy scores were calculated by summing each participant’s likelihood rankings of all scores that averaged below zero for the entire sample on bad/good rankings of items. Average ratings of scores appear in Table 2.

**Mood.** Current mood was assessed using the 9-item Mood Form (Diener & Emmons, 1984). Participants were asked to rate the degree to that they experienced each mood state at that moment on a scale from 0 ‘not at all,’ to 6 ‘extremely.’ Negative mood items were inversely scored. Items were summed to create an overall mood score. Overall mood ranged from -30 to 24 ($M = 5.58$, $SD = 9.99$).

**Results**

Data were analyzed using SPSS 19 statistical software. All variables were mean centered, and the condition variable was centered at zero; those in the experimental
condition were coded as .5, and those in the control condition were coded as -.5. Because the distribution for past 90-day marijuana use was highly positively skewed, square and cubed root transformations were attempted. Nevertheless, nearly half of the raw data distribution for past 90 day use reported zero—no standard transformation was able to fully reduce skew. We compared all analyses using several versions of the past 90-day marijuana use variable. All analyses were computed using the centered raw scores for past 90-day use, a square-root transformed distribution, the dichotomized past 90-day question (“Have you used marijuana in the past 90 days?”), and then with the use of bootstrapped samples with 5000 iterations. Main effects remained similar regardless of which distribution was used. The significance of our interaction term between past 90 day use and condition, however, was significant in predicting mood only when computed using raw scores and the dichotomized term. This finding raised concern, as the Type I error rate for spurious interactions are increased when a continuous variable is dichotomized in multiple regression (Maxwell & Delaney, 1993). We chose, therefore, to report all findings using bootstrapped samples, as bootstrapping is robust to interaction terms that include highly skewed raw score distributions (Preacher & Hayes, 2004), and bootstrapped results remained consistent with those using standard transformations. Thirteen participants voluntarily did not report whether they had ever used marijuana. Those participants were excluded from final analysis. Alpha was set at $\alpha = .05$.

A series of multiple regression equations were used to test our first two hypotheses. Past 90 day use, condition, and condition x use were entered into the equation in one block and regressed on mood, positive expectancy, negative expectancy, and craving. Due to the overrepresentation of women in the sample, gender was entered
as a covariate in all regression equations. The direction and significance of results were not dependent on whether gender was included or not. For ease of interpretation, therefore, all results are reported without the inclusion of gender in the analysis. Results for each equation appear in Table 3. Findings indicate that experimental condition predicts differences in craving and positive expectancies, but failed to reach significance for prediction of negative expectancies and mood. Those exposed to the experimental cue reported a higher likelihood of experiencing positively perceived outcomes of marijuana use than did controls ($M_{\text{exp}} = 1.03, SD_{\text{exp}} = 7.96; M_{\text{control}} = -1.03, SD_{\text{control}} = 8.82; d = .245$). Likewise, those in the experimental cue condition reported higher levels of craving than controls ($M_{\text{exp}} = 1.97, SD_{\text{exp}} = 1.15; M_{\text{control}} = 1.59, SD_{\text{control}} = .99; d = .354$). Past 90-day use for the whole sample also predicted higher positive expectancies, lower negative expectancies, and higher craving overall. Nevertheless, marijuana use did not significantly predict differences in mood. Finally, the interaction term of past 90 day marijuana use and condition type failed to reach significance for any of our dependent variables of interest. A correlation matrix of the uncontrolled association between all dependent variables appears in Table 4.

The first stage of analysis resulted in condition only significantly predicting positive expectancy likelihood and craving. Only positive expectancy, therefore, was analyzed for potential mediation between condition and craving. The direct effects of mood and negative expectancy on condition failed to reach significance, not providing sufficient indication to test for mediation. Although Baron and Kenny’s (1986) original method for testing mediation is the most commonly used, the test lacks power and is prone to issues of both Type I and Type II error inflation (Preacher & Hayes, 2004).
Instead, the Sobel test was chosen to evaluate the significance of the indirect pathway between condition, positive expectancy, and craving. The Sobel test creates a multiplicative term of the pathway between the predictor and mediator (α) and the correlation between the mediator and dependent variable (β), and tests the significance of the entire indirect pathway against the null (α x β = 0). The resulting distribution, however, will be the multiplicative term of two correlations, likely resulting in a strong positive skew. Therefore, a bootstrapping macro designed to run the Sobel test was used to examine the confidence intervals of the test term with a theoretical normal distribution (Bollen & Stine, 1990).

The Sobel test for the indirect effect of positive expectancy between condition and craving was significant (z = 1.99, p = .046, 95% CI = .001, .103) suggesting that changes in positive expectancy partially mediate the association between cue condition and craving.

**Discussion**

Our results provided partial support for our first and third hypotheses. Exposure to the experimental scent increased the likelihood that a participant would report that positive outcomes were likely to occur if they were to use marijuana. Ratings of overall current craving were also higher for those exposed to the scent of marijuana. Moreover, consistent with our third hypothesis, the positive association between cue exposure and craving was mediated by ratings of positive expectancies about marijuana use. Those exposed to the scent of marijuana reported that positive effects of using marijuana were more likely to occur than those not exposed to the smell, and this increase in positive expectancy was associated with reporting higher levels of current craving for marijuana.
Nevertheless, none of these associations were dependent on participants’ history of marijuana use. Also, our initial hypothesis that a positive association would exist between scent exposure and mood was not upheld by our findings. We also hypothesized that those exposed to the experimental scent would rate the likelihood of experiencing a negative effect after using marijuana as less likely than controls. This hypothesis was also not supported.

The present study is one of the first to analyze craving of marijuana in a sample of college students, an age group known to use marijuana the most. Moreover, these authors know of no other studies that have specifically implemented a primarily olfactory cue to test these hypothesized craving networks in marijuana—despite research that suggests a link between olfaction and mood-based memory (Herz et al., 2004). Mood-based memory activation is one mechanism that theoretically underlies expectancy change and craving following the presentation of conditioned cues. Exposure to marijuana is likely on college campuses (Pinchevsky et al., 2012). Students wishing not to use marijuana may be able to control their environments in ways that would limit exposure to visual cues associated with the drug. Nonetheless, the scent of marijuana is unique, easily perceived, and salient (Doty, Wudarski, Marshall, & Hastings, 2004). Because a large proportion of college students report lifetime use of marijuana (Johnston et al., 2012), it is likely that many students will be exposed to the smell often. The present study suggests that exposures such as these might make them more reactive to marijuana cues. When the scent of marijuana is perceived it may increase their desire to use.
Our findings suggest that history of marijuana use is associated with self-reported craving of marijuana. Those who report using marijuana the most are most likely to report current states of craving. Moreover, presentation of an olfactory cue also leads to increases in craving; however, this effect was not dependent on use history. One manifestation of the effect of increased craving after cue exposure is an increase in ratings of positive effects following the presentation of the cue. The presence of the olfactory cue leads to increases in ratings of the likelihood of experiencing a positive effect when using marijuana, which then leads to higher ratings of craving. Our findings suggest that mere exposure to the scent of marijuana, absent of other contextual elements, make positive outcomes of use more salient. The increased saliency of positive outcomes of use increases reported craving for the drug. These results are consistent with other findings in the craving literature. Nevertheless, previous work suggests that both positive and negative expectancies should shift if craving is to have occurred. We did not find a significant difference in ratings of likelihood of experiencing negative effects between those exposed to the scent and not. For college students it might be that exposure to olfactory cues shift beliefs about marijuana so that those exposed think it more likely that positive outcomes will occur if one were to use marijuana but do not downgrade the likelihood that negative outcomes will occur.

Conditioning models of craving also posit that mood might be one potential mediator of the overall “craving” effect. Mood changes associated with the effects of the drug should become associated with cues related to the drug and the various outcomes of intoxication. All of these elements are occurring in close proximity—taking the drug, experiencing the change in mood, and experiencing the outcome. With continued
parings we should see the cue, the beliefs about outcomes, and the mood associated with these outcomes change in synchrony. Nevertheless, no significant difference was seen between those exposed to the olfactory cue and controls on current mood. Exposure to the scent did not alter mood. This failure to find an effect might suggest that cue-activated expectancies might not be directly tied to specific mood-based memories, as was hypothesized. The rationale for using a primarily olfactory cue was to better trigger these mood-based memories, which we know to have a strong connection with olfaction (Herz et al., 2004). The prime of scent, however, might take a more direct route to inducing craving then through mood-related outcome memories. Mood changes do not seem to be the mechanism for craving of marijuana in response to cues.

Craving theory also suggests that cues, such as our experimental marijuana scent, should induce craving primarily in those with a strong history of use. We thought that those who used the most would be more reactive to the cue than those with less of a history with the plant. In theory, it should only be those who have experienced paired conditioning of the stimulus to the outcome who make the types of associations suggested by outcome-expectancy models. Moreover, other cognitive mediators of craving that have received support, such as attention to cues, theoretically occur because of continual dopamine receptor activation as a result of drug ingestion (i.e., continuously using). Nevertheless, the interaction term of past 90 day use and condition did not significantly predict any of our dependent variables above and beyond their main effects. Further investigation of the past 90-day use variable revealed a significant difference between groups in reported marijuana use history ($t = -2.286, p = .02$). Those in the experimental group reported a higher frequency of past 90 day marijuana use on average.
than did those in the control group ($M_{\text{control}} = 11.73, SD_{\text{exp}} = 29.06$), who were not exposed to the scent. The study’s group design was fully randomized, and control and experimental conditions did not differ on any of our demographic variables. There was no evidence to support that the difference found in average reported use could be spurious. This finding suggests that priming with the marijuana scent impacted how participants reported their marijuana use as well. The likely presence of this priming effect on differences in reporting of marijuana use means that we cannot draw well-founded conclusions from our analysis of the interaction term.

Our data also revealed several instances where a participant would self-report marijuana craving above the mean without having ever used marijuana. Marijuana use, however, is prevalent on college campuses, so outcome-expectancy learning might be occurring through modeling processes as well. It might not be necessary to have experienced the effects of the drug first hand to associate positive outcomes with the scent. That this association would then lead to increased self-reported craving, however, is curious.

The failure of the interaction term of past 90 day use and condition to meet significance and the prevalence of non-users reporting craving might suggest that “craving” of marijuana does not function in similar ways to other substances of abuse, such as alcohol. By asking college students to report their current craving of marijuana we might not be measuring “craving” in its classic sense, but perhaps some related term such as “liking” or “interest.” This concern is by no means new. Kozlowski and Wilkinson’s 1987 paper discussed the various connotations associated with word ‘craving,” and urged the field to head caution in using the general term ‘craving’
diagnostically. The spectrum of definitions for craving, ranging from the urge to relapse during drug treatment to extreme liking, will differentially predict whether or not problems exist. As marijuana use is relatively normative among college students, understanding cannabis craving from the vantage point of ‘strong interest in using the drug’ may not be indicative of problems in the same way that it might be for other intoxicants, such as cocaine or heroin. Moreover, how a marijuana user defines “craving” might be different than how a cocaine user experiences and defines it. The terms may not be equivalent across substances. Likewise, those with a history of marijuana use might understand “craving” differently than those with less experience with the drug. This raises an important psychometric question for craving researchers given that self-report questionnaires are the most common instruments used to measure craving. If we are seeing reports of cue-induced craving among those with little history of use, are we really quantifying “craving” in its classic sense when talking about marijuana? Nonetheless, our research does suggest that marijuana cues increase some level of desire to use the substance across college age user types. Future work is needed to determine the ramifications of self-reported “craving” of cannabis in comparison to other substances of abuse. Other work will also be needed to test the applicability of using olfactory cues in craving research involving other drugs.

**Limitations**

Our study is limited, in that our sample consisted of students in introductory psychology courses, and was predominantly female. Our sample also self-reported marijuana use well above national averages. Because our study was focused on craving
of marijuana, however, we did not see this as problematic. Nevertheless, future work is needed to determine whether our findings generalize to the college population at large.

Conclusion

Overall, our findings suggest that the presentation of olfactory cues increases the likelihood that college students believe positive outcomes will occur from using marijuana, which in turn increases reported craving to use compared to controls who are not exposed to olfactory cues for cannabis. Neither of these effects were dependent on history of use. These findings have clinical implications for the potential development of exposure interventions that seek to break the association between cues, such as smell, and outcome beliefs to reduce cue-induced craving.
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Table 1. Demographics of sample by condition.

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<th>%</th>
<th>n</th>
<th>%</th>
<th>ns</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>71</td>
<td>39.4%</td>
<td>68</td>
<td>39.5%</td>
<td>ns</td>
<td>139</td>
<td>39.5%</td>
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<tr>
<td>Sophomore</td>
<td>39</td>
<td>21.7%</td>
<td>31</td>
<td>18.0%</td>
<td></td>
<td>70</td>
<td>19.9%</td>
</tr>
<tr>
<td>Junior</td>
<td>38</td>
<td>21.1%</td>
<td>45</td>
<td>26.2%</td>
<td></td>
<td>83</td>
<td>23.6%</td>
</tr>
<tr>
<td>Senior</td>
<td>31</td>
<td>17.2%</td>
<td>28</td>
<td>16.3%</td>
<td></td>
<td>59</td>
<td>16.8%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0.6%</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>1</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>ns</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American</td>
<td>13</td>
<td>7.2%</td>
<td>22</td>
<td>12.8%</td>
<td></td>
<td>35</td>
<td>9.9%</td>
</tr>
<tr>
<td>American Indian</td>
<td>1</td>
<td>0.6%</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>1</td>
<td>0.3%</td>
</tr>
<tr>
<td>Asian</td>
<td>21</td>
<td>11.7%</td>
<td>17</td>
<td>9.9%</td>
<td></td>
<td>38</td>
<td>10.8%</td>
</tr>
<tr>
<td>Caucasian</td>
<td>118</td>
<td>65.6%</td>
<td>109</td>
<td>63.4%</td>
<td></td>
<td>227</td>
<td>64.5%</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>17</td>
<td>9.4%</td>
<td>16</td>
<td>9.3%</td>
<td></td>
<td>33</td>
<td>9.4%</td>
</tr>
<tr>
<td>Native Hawaiian/Pacific Islander</td>
<td>10</td>
<td>5.6%</td>
<td>7</td>
<td>4.1%</td>
<td></td>
<td>1</td>
<td>0.3%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0.0%</td>
<td>1</td>
<td>0.6%</td>
<td></td>
<td>17</td>
<td>4.8%</td>
</tr>
</tbody>
</table>
Table 2. Mean and SD of Likelihood and Positive/Negative Ratings for Expectancy Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean Pos/Neg</th>
<th>SD</th>
<th>Mean Likelihood</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would become less tense</td>
<td>1.22</td>
<td>.99</td>
<td>.37</td>
<td>1.55</td>
</tr>
<tr>
<td>I would be more creative or imaginative</td>
<td>1.30</td>
<td>.928</td>
<td>.11</td>
<td>1.49</td>
</tr>
<tr>
<td>I would become forgetful</td>
<td>-1.39</td>
<td>.77</td>
<td>.44</td>
<td>1.42</td>
</tr>
<tr>
<td>I would have a good time</td>
<td>1.34</td>
<td>.92</td>
<td>.43</td>
<td>1.42</td>
</tr>
<tr>
<td>I would be giddy or exuberant</td>
<td>.87</td>
<td>1.10</td>
<td>.26</td>
<td>1.43</td>
</tr>
<tr>
<td>I would lose motivation to do the things I need to do</td>
<td>-1.60</td>
<td>.68</td>
<td>.39</td>
<td>1.46</td>
</tr>
<tr>
<td>I would get the &quot;munchies&quot; (craving for snacks)</td>
<td>-.43</td>
<td>1.04</td>
<td>.78</td>
<td>1.41</td>
</tr>
<tr>
<td>It would be easier to talk to people</td>
<td>.78</td>
<td>1.09</td>
<td>-.45</td>
<td>1.45</td>
</tr>
<tr>
<td>I would become angry and possibly violent</td>
<td>-1.84</td>
<td>.56</td>
<td>-1.70</td>
<td>.79</td>
</tr>
<tr>
<td>I would experience music in a different way</td>
<td>.89</td>
<td>1.01</td>
<td>.20</td>
<td>1.49</td>
</tr>
<tr>
<td>I would not be able to express my thoughts clearly</td>
<td>-1.40</td>
<td>.84</td>
<td>-.32</td>
<td>1.44</td>
</tr>
<tr>
<td>I would laugh more than usual</td>
<td>.84</td>
<td>1.08</td>
<td>.81</td>
<td>1.39</td>
</tr>
<tr>
<td>I would become addicted to marijuana</td>
<td>-1.67</td>
<td>.74</td>
<td>-1.75</td>
<td>.757</td>
</tr>
<tr>
<td>I would experience a sense of relaxation</td>
<td>1.21</td>
<td>.98</td>
<td>.71</td>
<td>1.35</td>
</tr>
<tr>
<td>I would become paranoid</td>
<td>-1.65</td>
<td>.60</td>
<td>-.32</td>
<td>1.48</td>
</tr>
<tr>
<td>I would chill out</td>
<td>1.11</td>
<td>1.02</td>
<td>.63</td>
<td>1.35</td>
</tr>
<tr>
<td>I would act sociable</td>
<td>1.04</td>
<td>.967</td>
<td>.00</td>
<td>1.38</td>
</tr>
<tr>
<td>I would lose control and become careless</td>
<td>-1.63</td>
<td>.72</td>
<td>-1.12</td>
<td>1.21</td>
</tr>
<tr>
<td>I would have a good time</td>
<td>1.30</td>
<td>.92</td>
<td>.52</td>
<td>1.37</td>
</tr>
<tr>
<td>I would feel down after the &quot;high&quot; of smoking marijuana</td>
<td>-1.44</td>
<td>.78</td>
<td>-.75</td>
<td>1.35</td>
</tr>
<tr>
<td>I would be happy</td>
<td>1.35</td>
<td>.97</td>
<td>.39</td>
<td>1.35</td>
</tr>
<tr>
<td>I would let my friends and/or family down</td>
<td>-1.76</td>
<td>.64</td>
<td>-.22</td>
<td>1.67</td>
</tr>
</tbody>
</table>
### Table 3. Past 90-day Marijuana Use and Cue Condition as Predictors of Craving (N = 352)

<table>
<thead>
<tr>
<th>DV</th>
<th>Predictor</th>
<th>β</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 day use</td>
<td>0.013</td>
<td>&lt;.001*</td>
<td>.009 - .022</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>0.272</td>
<td>0.013*</td>
<td>.052 - .464</td>
<td></td>
</tr>
<tr>
<td>Use x Condition</td>
<td>-0.006</td>
<td>0.374</td>
<td>-0.018 - .011</td>
<td></td>
</tr>
<tr>
<td>Mood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 day use</td>
<td>0.015</td>
<td>0.414</td>
<td>-.026 - .05</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>1.082</td>
<td>0.320</td>
<td>-1.055 - 3.28</td>
<td></td>
</tr>
<tr>
<td>Use x Condition</td>
<td>0.038</td>
<td>0.290</td>
<td>-.024 - .128</td>
<td></td>
</tr>
<tr>
<td>Positive Expectancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 day use</td>
<td>0.032</td>
<td>0.008*</td>
<td>.01 - .062</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>1.834</td>
<td>0.034*</td>
<td>.104 - 3.485</td>
<td></td>
</tr>
<tr>
<td>Use x Condition</td>
<td>-0.004</td>
<td>0.882</td>
<td>-.054 - .044</td>
<td></td>
</tr>
<tr>
<td>Negative Expectancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 day use</td>
<td>0.042</td>
<td>&lt;.001*</td>
<td>.027 - .073</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>1.124</td>
<td>0.184</td>
<td>-.547 - 2.702</td>
<td></td>
</tr>
<tr>
<td>Use x Condition</td>
<td>0.016</td>
<td>0.430</td>
<td>-.064 - .034</td>
<td></td>
</tr>
</tbody>
</table>

Note. Use x Condition = product of past 90 day use and condition code.

*Significant at p < .05
Table 4. Correlation Matrix of all Dependent Variables

(N = 352)

<table>
<thead>
<tr>
<th></th>
<th>Condition</th>
<th>Craving</th>
<th>Pos. Expectancy</th>
<th>Neg. Expectancy</th>
<th>Mood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>−</td>
<td>0.176**</td>
<td>.122**</td>
<td>0.093</td>
<td>0.058</td>
</tr>
<tr>
<td>Craving</td>
<td>.176**</td>
<td>−</td>
<td>.215**</td>
<td>.302**</td>
<td>.121*</td>
</tr>
<tr>
<td>Pos. Expectancy</td>
<td>.122*</td>
<td>.215**</td>
<td>−</td>
<td>.764*</td>
<td>0.039</td>
</tr>
<tr>
<td>Neg. Expectancy</td>
<td>0.093</td>
<td>.302**</td>
<td>.764**</td>
<td>−</td>
<td>0.078</td>
</tr>
<tr>
<td>Mood</td>
<td>0.058</td>
<td>.121*</td>
<td>0.039</td>
<td>0.078</td>
<td>−</td>
</tr>
</tbody>
</table>

**Correlation significant at \( p < .01 \)

*Correlation significant at \( p < .05 \)