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Sex Differences in the Relationship between Cannabis Use Motives and Cannabis Craving in Daily Life in Emerging Adults

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Abstract

Objective: Cannabis use motives and craving are associated with increased risk for cannabis-related problems and are ideal targets for prevention and early intervention. Patterns of motives and craving reactivity to cannabis cues differ by sex; however, few studies closely examine the relationship between motives and craving and how it may differ by valence (+/−) across men and women.

Method: The current study used cue-reactivity ecological momentary assessment (CREMA) to assess reward (+) and relief (−) craving four semi-random times per day for two weeks in a sample of 63 emerging adults (age 18–21; 54% cisgender women; 85.7% white) who frequently use cannabis (≥3 times per week). We assessed craving before and after exposure to brief neutral or cannabis image cues and examined within- and between-participant effects of cue type, motives, sex/gender, and their interactions, on post-cue cannabis craving.

Results: Regardless of cue type, women with high coping motives (−) reported less post-cue relief (−) craving, and men with high enhancement motives (+) reported more post-cue reward (+) craving. High enhancement motives (+), regardless of sex/gender, were associated with elevated relief (−) craving reactivity to cannabis cues, and women with high coping motives (−) reported elevated reward (+) craving reactivity to cannabis cues.

Conclusions: Sex/gender differences in the relationships between cannabis motives and craving reactivity indicate the value of more targeted examination of valence (+/−) of craving experiences in addition to motives for use. Higher levels of precision may better inform interventions for emerging adults at risk for experiencing cannabis-related problems.

Keywords

cue reactivity; ecological momentary assessment; cannabis craving; cannabis motives; sex/gender differences

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Introduction

Approximately one quarter of emerging adults (age 18–25) have used cannabis in the past month, and around 8% use cannabis daily (Center for Behavioral Health Statistics and Quality, 2021). With broadening decriminalization and legalization efforts across the United States, rates of use are likely to continue increasing. Although most emerging adults who use cannabis will not go on to develop cannabis use disorder (CUD), some will. In fact, the onset of a CUD typically occurs between 18 and 21, and emerging adults have the highest proportion of individuals meeting criteria for a past year CUD at approximately 14% (Center for Behavioral Health Statistics and Quality, 2021; Farmer et al., 2015). Thus, emerging adulthood is a critical period in which to closely examine cannabis use and determine how to intervene most effectively to reduce the risk of developing a CUD.

The decision to use a substance is, in part, based on how an individual weighs the potential incentives for use versus incentives not to use in the moment. This motivational model proposes that the typical incentive to use is a desired change in affect, specifically tension reduction (negative reinforcement) or mood enhancement (positive reinforcement) (Cox & Klinger, 1988). Motives for use are characterized in relation to the valence (negative reinforcement/“avoidance” vs. positive reinforcement/ “approach”) and source (internal vs. external) of the outcomes an individual hopes to achieve through use (Cooper, 1994). This 2-valence × 2-source model, originally developed for alcohol use motives, identifies four potential reasons someone might decide to use: coping (avoidance, internal), enhancement (approach, internal), conformity (avoidance, external), and social (approach, external). Although they are a relatively stable characteristics, motives for use differ between individuals and can differ within an individual or be altered or modified over time (Blevins et al., 2016, 2018). Importantly, endorsing numerous strong motives, especially enhancement and coping, for cannabis use is associated with higher use and related negative consequences in emerging adults, and emerging adults endorse enhancement and coping motives at higher frequencies than other motives (Bresin & Mekawi, 2019; Espinosa et al., 2022). Additionally, coping motives have been associated with elevated craving (Farris et al., 2016; Peraza et al., 2019), a potentially aversive, distressing, or unwanted experience that can interfere with quality of life (see Tiffany & Wray, 2012).

Craving may be triggered by internal (e.g., “negative/positive” emotions) or external sources (e.g., exposure to cannabis paraphernalia). In the motivational model, craving could be considered an internal source for affect change, which suggests that craving may also have valence (i.e., approach and avoidance) and would inform valence-congruent motives. Prior theories relevant to substance craving describe both approach and avoidance-based craving (Jellinek et al., 1955; Ludwig & Wikler, 1974; Marlatt, 1978; Wise, 1988), and a commonly used craving questionnaire identified two craving factors, one associated with avoidance or “relief” from negative affective/physiological states and the second associated with approach or “reward” from the positive effects of cannabis (see Heishman et al., 2009 and Romero-Sanchiz et al., 2022). A cue-exposure paradigm study with individuals with PTSD demonstrated the utility in examining craving along these two factors. Relief craving was elevated following trauma cues and reward craving was elevated following cannabis

cues (relative to neutral cues); however, inconsistent with prior theories, reward craving was also elevated following trauma cues and one form of relief craving (emotionality) was elevated following cannabis cues (Romero-Sanchiz et al., 2022). Therefore, craving reactivity to conditioned cues may not be as straightforward as previously thought.

With many interventions for substance use disorders often including a component on identifying triggers (cues for use) and providing strategies to manage the craving that can follow, some research suggests that the valence of the craving may be important for individuals to be able to respond to it in a healthy/helpful way. However, craving experiences are generally short-lived, potentially making it difficult for CUD interventions to adequately target distinct craving experiences with the appropriate or most relevant strategies. Motives are the reasons people say they use a substance, and, as mentioned, may be informed by craving experiences. In addition, motives may be an important intervention focus that can be more easily targeted within a treatment session. Thus, better understanding the relationship between motives and valence-congruent/-incongruent craving in response to cannabis triggers can inform intervention approaches to providing the most relevant strategies to manage craving in the moment.

Cue Reactivity Ecological Momentary Assessment

Cue Reactivity Ecological Momentary Assessment (CREMA) is a methodological approach that incorporates the cue reactivity paradigm into frequently administered real-time assessments within an individual's natural environment (Warthen & Tiffany, 2009). Although standard EMA is an effective method to collect data on frequently occurring and dynamic phenomena, such as craving, in real time (Stone & Shiffman, 1992, 1994), CREMA allows researchers to assess the same variables before and after the systematic administration of standardized cues. Thus, certain causal inferences related to cue exposures over multiple administrations are possible with CREMA that may not be with standard EMA procedures. Prior research has demonstrated the ability of CREMA procedures to successfully induce craving and negative affect/stress in adults who smoke cigarettes (Tomko et al., 2020; Warthen & Tiffany, 2009; Wray et al., 2015), and negative affect/stress in emerging adults who frequently use cannabis (Gex et al., 2022). The current study will be the first to assess the ability of cannabis cues administered using CREMA procedures to induce craving in the natural environments of a sample of emerging adults who frequently use cannabis.

Sex Differences in Cannabis Use Motives and Craving

Cannabis Use Motives—Research indicates that there are meaningful sex differences in motives for cannabis use; however, findings are somewhat mixed. Whereas a few studies have observed sex differences in the endorsement of motives (Buckner et al., 2012; Espinosa et al., 2022), others have not (Comeau et al., 2001). Specific to enhancement and coping motives, men tend to endorse more enhancement motives and women tend to endorse coping motives (Espinosa et al., 2022). There is also evidence that it is the role cannabis use motives play in the relationship between phenomena that is different across men and women; however, some inconsistencies persist. For example, in women, coping motives have been associated with greater cannabis use and are implicated in the relationship

between distress tolerance and cannabis related problems (Bujarski et al., 2012; Simons et al., 1998). However, in both men and women who use cannabis, coping motives have been associated with social anxiety (Buckner et al., 2012; Morris & Buckner, 2023). Further, in women, social anxiety was associated with enhancement motives (Buckner et al., 2012). Alternatively, in a sample of adolescents and emerging adults, borderline personality features were predictive of coping motives in boys and enhancement motives in girls (Chabrol et al., 2005). Taken together, this suggests that motive endorsement, while somewhat tied to sex/gender, may be expressed differently, also as a function of sex/gender, when considering contextual factors such as mood/anxiety disorders or other psychopathology.

Cannabis Cue-Induced Craving—Sex/gender also appears to modify craving reactivity to cannabis cues. Whereas men and women with cannabis dependence demonstrate similar self-reported craving reactivity magnitudes (Lundahl & Johanson, 2011), neuroimaging findings indicated that cannabis craving appears to be associated with insula reactivity in women (Garavan, 2010; Naqvi et al., 2014) and striatal reactivity in men (Daniel & Pollmann, 2014; Koob & Volkow, 2010). Insula responsivity in women is suggestive of a bias towards relief-centric craving (see Heishman et al., 2009), whereas striatal reactivity in men suggests a bias towards reward-centric craving. These findings highlight the possibility that variation in the neural circuitry involved in responses to cannabis cues subserves sex differences in craving motivation/valence; specifically, negative, relief-based cannabis craving in women and positive, reward-based cannabis craving in men.

The current study

To our knowledge, the current study is the first to examine valence-specific craving reactivity to cannabis cues using CREMA methodology, and only the second to leverage this methodology in a sample of individuals who use cannabis frequently (see Gex et al., 2022). Prior laboratory research in cannabis craving reactivity (Gray et al., 2008; Henry et al., 2014) and CREMA studies in adult cigarette smokers (Tomko et al., 2020; Warthen & Tiffany, 2009; Wray et al., 2015) suggest that cannabis craving will increase in response to brief presentations of pictorial cannabis cues in our sample of emerging adults who frequently use cannabis. Further, we expected that motives for cannabis use would be associated with craving of a congruent valence (positive “reward” vs. negative “relief”) prior to exposure to a cannabis image cue (“tonic” craving). We then expected that higher motives for cannabis use would also be associated with elevated craving of a congruent valence in response to exposure to a cannabis image cue (craving reactivity). Specifically, baseline coping motives would be positively associated with relief craving following a cannabis cue relative to a neutral cue (coping motives × cue type), and baseline enhancement motives would be positively associated with reward craving following a cannabis cue relative to a neutral cue (enhancement motives × cue type). We also explored these same relationships between coping and enhancement motives and “incongruent” craving, i.e., reward and relief respectively. Finally, considering prior research has demonstrated sex differences in cannabis use motives and craving, we hypothesized that sex would interact with motives (sex × coping motives; sex × enhancement motives) to predict post-cue craving, and we explored sex differences in craving reactivity to cannabis cues (sex × cue type). Although prior

research is somewhat mixed, we expected that women might report higher relief craving in response to cannabis cues, particularly if they endorse greater coping motives.

Method

Participants were 63 cannabis-using emerging adults aged 18–21 (34 women, 54%; M = 19.62, SD = 1.04) who reported using cannabis at least 3 times per week over the past 30 days ($M_{\text{days used}}$ = 25.11, SD = 6.75). Cannabis use eligibility criteria were confirmed by a positive oral fluid cannabinoid test (Δ^9-tetrahydrocannabinol, THC; Forensic Fluids Laboratories) for remote-only participants (recruited/enrolled amid COVID-19 precautions) or urine sample (semi-quantitative cannabinoid immunoassay) for in-person participants. Participants could not be planning to quit or reduce their cannabis use in the next month, have a severe substance use disorder requiring higher level/immediate care, be currently enrolled in treatment for substance use, be pregnant or lactating, or have any severe condition that could interfere with study procedures. Participants completing the study entirely remotely also had to be accessible via videoconference, have access to a local UPS drop-off location, and own an iOS device for CREMA app use. Six people were ineligible for remote-only participation at the screening stage due to not having an iOS device. Notably, remote-only participants made up only 12.7% (n = 8) of the sample.

We recruited participants from communities across the state of South Carolina using local multimedia campaigns (e.g., Instagram and Facebook advertising, flyers). Interested individuals completed a brief phone screen, and those potentially eligible were scheduled for a baseline visit. Informed consent was obtained prior to initiating any study procedures. In-person participants completed a screening session during which they submitted a urine sample for cannabinoid analysis. Remote-only participants submitted an oral fluid sample by mail. We screened 80 participants, 11 of whom we excluded following screening and 3 of whom did not return to complete further study visits (i.e., declined to participate or were unable to be contacted). Sixty-six eligible participants initiated the baseline visit which consisted of assessments and orientation to the CREMA protocol, however, two did not complete the full assessment battery and one only completed the first week of the two-week CREMA period (see Figure 1). At the baseline visit, participants were oriented to the CREMA procedures and selected four 2-hour time blocks during which a CREMA session would be randomly administered each day.

CREMA sessions followed procedures similar to those of the initial study that developed and tested CREMA software on personal digital assistant (PDA) computers (see Warthen & Tiffany, 2009). In the current study, in-person participants were provided an Apple iPhone or were asked to download the iOS compatible CREMA app to their personal iPhone (see Wray et al., 2015). Each CREMA session first assessed current affect, craving, any recent stressors, and time since they last used cannabis. Then, participants were shown an image cue (i.e., neutral, negative affective/stress, or cannabis) for 10 seconds. Neutral and negative affective images were selected from the International Affective Picture System (IAPS; Lang et al., 2008) and/or prior CREMA studies (Warthen & Tiffany, 2009; Wray et al., 2015). Cannabis images were selected from a previously validated cannabis cue reactivity task for emerging adults (Karoly et al., 2019). We selected the first 32 of 36 cannabis images from

the task, 20 of which were 'passive' (i.e., picture of cannabis leaf or bud, paraphernalia) and 12 'active' (i.e., people smoking cannabis). The four excluded images were passive, though there was no systematic process to this decision. We selected 21 neutral images, 11 of which were 'passive' (i.e., pictures of objects like flowers, sunglasses, colored pencils) and 10 of which were 'active' (i.e., people blowing bubbles, drinking a glass of water, applying lipstick). By design, images were not to repeat,[1] and each cue type was to be presented at least once per day in a random order, totaling up to four cues presented on a study day. Participants did not receive all possible images. For the current study analyses, we included only CREMA sessions presenting either a neutral cue or a cannabis cue. Following the cue, craving and affect were assessed again. Of the 2639 completed CREMA sessions, 1014 presented cannabis cues and 662 presented neutral cues. Additional study procedure details have been published previously (see Gex et al., 2022). All procedures were approved by the Medical University of South Carolina Institutional Review Board.

Measures

Demographics.—We collected demographic information, including sex-assigned-at-birth and gender identity, race and Hispanic/Latino/a/x ethnicity, education ("What was the last grade of school you completed?"), employment, and perceived socioeconomic status using the MacArthur Scale of Subjective Socioeconomic Status (Adler et al., 2000). Both sex ("what sex were you assigned at birth, meaning on your original birth certificate?") and gender identity ("what is your gender identity?") were collected at baseline. For the first item, participants could select either "male" or "female." For the second item, participants could select "male," "female," "trans male/trans man," "trans female/trans woman," or "different identity" and were asked to specify. Sex-assigned-at-birth was used in our analyses because all participants identified as cisgender. However, we acknowledge that gender is not binary and that our sample is not representative of gender diverse individuals (see Heidari et al., 2016).

Cannabis use motives.—Motives were assessed once at baseline using the Marijuana Motives Measure (MMM; Simons et al., 1998), a 25-item measure that consists of five subscales: Coping, Enhancement, Social, Conformity, and Expansion. Each subscale includes five items which were averaged to create the subscale scores. Participants responded to each item on a scale from 1 (*Almost never/never*) to 5 (*Almost always/always*). Lower subscale scores indicate less frequent use related to that motive, and higher scores indicate more frequent use related to that motive. Example items from each subscale include "to forget about my problems" (coping), "because I like the feeling" (enhancement), "to be sociable" (social), "so I won't feel left out" (conformity), and "to expand my awareness" (expansion). Our analyses focus only on the Coping and Enhancement subscales because these are the internal, positive and negative valenced motives of interest and have also been consistently linked to cannabis use frequency and related problems (Bresin & Mekawi, 2019). Internal consistency was 0.86 and 0.77, respectively.

[1]Due to an app error early in the study, if participants needed to re-download the CREMA app at any point during their study participation, they may have experienced a small number of duplicate cues.

Cannabis Use Disorder.—Severity of cannabis use disorder (CUD) was assessed using the Mini International Neuropsychiatric Interview (MINI) for the DSM-5 (Sheehan et al., 1998). Trained clinical interviewers used participant responses and their clinical judgment to select "yes" or "no" for each symptom. As defined in the DSM-5, endorsement of 0–1 symptoms indicated no use disorder, 2–3 symptoms a mild use disorder, 4–5 moderate, and 6 or more severe. Internal consistency was 0.67.

Recent cannabis use.—At the beginning of each CREMA session, participants reported on "how long has it been since you last used cannabis/marijuana?" Participants could select "0–29 min," "30–59 min," "1–3 h," or "more than 3 h ago." For the models, we dummy coded this variable to 0 (*less than 1 h*) and 1 (*more than 1 h*), accounting for the possibility that more recent cannabis use may attenuate craving.

Craving.—Cannabis craving was assessed at baseline and twice within each CREMA session (once before image cue exposure and once after). At baseline, the 12-item Marijuana Craving Questionnaire Short Form (MCQ-SF) was used (Heishman et al., 2009). It consists of four subscales: Emotionality, Compulsivity, Purposefulness, and Expectancy. Each subscale includes three items and was scored by averaging the item ratings, which were on a Likert-type scale ranging from 1 to 7 with anchors at 1 (*Strongly disagree*), 4 (*Neither agree nor disagree*), and 7 (*Strongly agree*). Low scores indicate low levels of craving and high scores indicate high levels of craving. Consistent with our current aims, we focused on the Emotionality subscale items to capture "relief" craving and the Purposefulness subscale items to capture "reward" craving. Example items from these subscales include, "I would feel less anxious if I smoked marijuana right now" (emotionality) and "Smoking marijuana would be pleasant right now" (purposefulness). Internal consistency at baseline was 0.77 for the Emotionality subscale and 0.82 for the Purposefulness subscale.

For the CREMA sessions, we used the Momentary Cannabis Craving Scale (Davis et al., *manuscript under review*) which is a brief 6-item scale consisting of two factors with 3 items each: Purposefulness/General Desire to Use and Emotionality/Negative Affect. The Purposefulness/General Desire to Use subscale (hereafter 'reward') consists of two items from the MCQ-SF Purposefulness subscale and one item assessing general desire to use ("I have a desire to use marijuana right now"). The Emotionality/Negative Affect subscale (hereafter 'relief') consists of all three items from the MCQ-SF Emotionality subscale. We slightly modified the items following exposure to the image cue to add, "WHILE LOOKING AT THE PHOTOGRAPH…" before the originally worded item. It should be noted that not all participants (n =17) received the reward subscale items because they were added part way through the study.

Negative affect.—Considering that the current study focuses on internally sourced motives and that negative affect is an internal experience expected to affect motives and craving, baseline negative affect was included as a covariate in all models. This was assessed using the Depression, Anxiety, and Stress Scale (DASS-21; Lovibond & Lovibond, 1995). Participants responded to 21 items on a 4-point scale from 0 (*Not at all true*) to 3 (*Extremely true*). The measure consists of three subscales: Depression, Anxiety, and Stress, and each include seven items which are summed to create the subscale scores. Example items include,

"I couldn't seem to experience any positive feeling at all" (depression), "I felt I was close to panic" (anxiety), and "I found it hard to wind down" (stress). For simplicity, all 21 items were summed together to create a single total score. Internal consistency for the full scale in the current sample was 0.93.

Fidelity checks.—To increase certainty that participants were responding to the cue, two fidelity checks were included in each CREMA session. Following the post-cue craving assessment, participants were asked to provide responses to the following items: (1) "Were you able to see the photograph?" (yes/no) and (2) "I looked carefully at the photograph" (using a five-point Likert-type scale with anchors at 1 *Strongly disagree*, 3 *Moderately agree*, and 5 *Strongly agree*). Fidelity check items were used to evaluate and exclude potentially invalid responses to cues. For example, if a participant indicated they could not see the photograph (answered "no" to item 1) and/or slightly or strongly disagreed that they had looked carefully at the photograph (answered 1 or 2 to item 2), their response ratings on post-cue affect and craving were considered invalid and thus excluded.

Statistical Analysis

Baseline descriptive statistics for all participants who completed the two-week period of CREMA sessions ($N = 63$)[2] were conducted using SPSS (Statistics for Mac, Version 27.0, Released 2020; IBM Corp., Armonk, NY). Baseline data were examined for univariate outliers (values more than 3.29 standard deviations away from the mean) as well as skewness and kurtosis. No univariate outliers were corrected, and no variables were power transformed. Bivariate Pearson correlations were conducted between continuous baseline variables of interest. *T*-tests and χ^2 tests were also conducted to examine differences by sex. CREMA session data were first examined for missingness. With up to four possible CREMA sessions per day over 14 days in 63 participants, there was a possible total of 3528 CREMA sessions. Compliance was adequate and similar to other EMA studies (Jones et al., 2019). The average number of completed sessions was 42 (74.7%) of the possible 54, and the majority of our participants (68.2%) completed at least 70% of the CREMA sessions. Figure 2 provides a flowchart of missing and removed CREMA session data and the reasons for removal. Approximately 25% ($n = 893$) were considered missing because the participant either did not start the CREMA session following the prompt or they did not complete the CREMA session to the point at which they would have viewed the image cue. Sixty-nine (2.62%) post-cue observations were considered missing because participants endorsed that they were unable to see the image ($n = 15$) and/or they did not look carefully at the image (rating < 3 *Moderately agree* on the second fidelity check; $n = 54$). Eighteen of these excluded observations were cannabis cues, and 18 neutral cues. Another 24 (0.9%) post-cue observations were removed because the fidelity check items were not completed. Ten were cannabis cues, and six were neutral cues. Thus, we retained 2542 CREMA sessions in which participants completed pre-cue items, adequately viewed the image cue, and completed post-cue items. Because we were interested in examining craving reactivity to cannabis cues relative to neutral cues, we excluded 918 CREMA sessions that administered a

[2]Although 64 participants completed the baseline assessment and initiated the CREMA protocol, one participant only completed one week of the CREMA protocol and was thus removed from the analyses.

stress/negative affective cue from our available 2542 completed observations. For models examining relief craving reactivity, this resulted in 1624 observations for analysis across all 63 participants. Pre- and post-cue reward craving items were not added until later in the study, so the first 17 participants are missing these data across 750 CREMA sessions. Tonic reward craving models included 1792 CREMA sessions, and reward craving reactivity models included 1146 CREMA sessions across 46 participants.

To address our hypotheses, we used two-level random slopes multilevel models in M*plus* version 8.6 (Múthen & Múthen, 1998-2017) as it accommodates unequally spaced time intervals, varying numbers of observations across participants, and within-participant variance (Gibbons et al., 2010). Residual diagnostics indicated that our assumptions of linearity and homoscedasticity were satisfactory. Histograms of our pre- and post-cue relief and reward craving were somewhat positively skewed; therefore, all models used robust maximum likelihood estimation (MLR), which accommodates non-normally distributed data and helps derive robust standard errors when missing data are present (Enders, 2010). For motives predicting tonic craving, 10 multilevel models examined the main effects of coping, enhancement, social, expansion, and conformity motives on pre-cue relief and reward craving. In these models, motives were included in level 2 (between-participant fixed effects) along with the covariates sex assigned at birth, past 30-day cannabis use frequency (in days), and negative affect (DASS total score). In level 1, relative time of day (session number) and the binary variable time since last cannabis use (less than 1 hour ago, more than 1 hour ago) were included as random slopes on pre-cue relief and reward craving.

Our cue reactivity models focused on enhancement and coping motives as predictors of relief and reward craving. We conducted four main effects models: (1) baseline coping motives predicting post-cue relief craving, (2) baseline enhancement motives predicting post-cue reward craving, (3) baseline enhancement motives predicting post-cue relief craving, and (4) baseline coping motives predicting post-cue reward craving. We included the same level 2 covariates as in the tonic models, as well as grand-mean-centered[3] pre-cue relief and reward craving, respectively. Grand-mean-centered pre-cue craving variables account for the typical level of craving found across all participants. In level 1 of the models, random slopes were defined for the relationships between post-cue craving and (a) relative time of day (session number), (b) binary time since last cannabis use, (c) cue type (neutral vs. cannabis), and (d) person-mean-centered[4] pre-cue craving. Person-mean-centered pre-cue craving variables account for the typical level of craving found within participants across time.

Additional models examined the following cross-level and between-level interactions: cue (neutral vs. cannabis) × motives (low/high coping; low/high enhancement), cue × sex (men, women), and sex × motives. We also examined the three-way interaction sex × motives ×

[3]To grand-mean-center our pre-cue craving variables, we calculated the mean for each participant and using those means, calculated the grand mean. We then subtracted the grand mean from the mean for each participant. These values did not vary within the participant and thus were included in level 2.

[4]To person-mean-center our pre-cue craving variables, we calculated the mean for each participant and subtracted the participant's mean from each observation's pre-cue craving. These values vary within the participant and thus were included in level 1.

cue. Per recommendations in Snijders and Bosker (2011), we retained interaction terms if they reached a significance level of $p < 0.05$.

Results

Descriptive Statistics and Correlations

Table 1 presents the demographic characteristics and baseline cannabis use, motives, craving, and CUD severity, as well as negative affective symptoms, for the full sample and by sex. There were no significant sex differences in motives or craving at baseline; however, differences in bivariate correlations by sex were observed. Table 2 presents the results of bivariate Pearson *r* correlations between baseline predictors and correlates for the full sample and by sex, as well as effect sizes for sex differences. Overall, coping and enhancement motives were significantly associated with relief and reward craving. In men, enhancement motives were strongly associated with baseline relief and reward craving, and baseline reward craving was more strongly associated with past 30-day cannabis use, relative to women.

Tonic Craving

Table 3 presents results from models in which motives predicted craving prior to cue exposure in CREMA sessions (tonic craving). ICCs for pre-cue relief and reward craving were 0.68 and 0.60, respectively, indicating that 32% of the variance in pre-cue relief craving and 40% of the variance in pre-cue reward craving was at the within-participant level. Only baseline enhancement motives were significantly associated with tonic relief (B = 1.016, SE = 0.186, $p < 0.001$) and reward craving (B = 1.188, SE = 0.241, $p < 0.001$).

Craving Reactivity

Cannabis cue type was significantly associated with increased post-cue relief (B = 0.623, SE = 0.084, $p < 0.001$) and reward craving (B = 1.139, SE = 0.133, $p < 0.001$), and these models accounted for typical pre-cue craving across participants and typical pre-cue craving within participants. Table 4 presents results from models in which coping and enhancement motives predicted post-cue relief and reward craving, respectively, as well as all retained interaction effects. ICCs for post-cue relief craving and reward craving were 0.629 and 0.532, respectively, indicating that 37% of the variance in post-cue relief craving and 47% of the variance in post-cue reward craving was at the within-participant level. Coping motives were significantly associated with post-cue relief craving (B = −0.147, SE = 0.070, $p = 0.036$), however, this was regardless of cue type. The coping motives × cue type interaction was not significant and thus not retained. Enhancement motives were not significantly associated with post-cue reward craving, and the enhancement motives × cue type interaction was not significant.

Enhancement motives interacted with cue type to predict post-cue relief craving (B = 0.240, SE = 0.115, $p = 0.037$) (see Table 5). A simple slopes analysis showed that there was more relief craving reactivity to cannabis cues (B = 0.796, SE = 0.140, $p < 0.001$) relative to neutral cues (B = 0.457, SE = 0.088, $p < 0.001$) and that those with high enhancement motives responded more strongly to both cues relative to those with low enhancement

motives, and both slopes were statistically significant (Figure 3). Additionally, there was a coping motives × sex/gender × cue type three-way interaction predicting post-cue reward craving reactivity (B = 0.613, SE = 0.211, $p = 0.004$) (see Table 5). Simple slopes analysis showed that women with high coping motives reported greater reward craving reactivity to cannabis cues relative to neutral cues (B = 1.634, SE = 0.168, $p < 0.001$) and relative to men with high coping motives. The simple slopes for men with high coping motives (B = 0.572, SE = 0.187, $p = 0.002$), and men (B = 1.075, SE = 0.217, $p < 0.001$) and women (B = 0.909, SE = 0.320, $p = 0.004$) with low coping motives were all significant (Figure 4).

Sex Differences in Motives Predicting Post-Cue Craving

Although neither coping or enhancement motives interacted with cue type to predict post-cue relief and reward craving, respectively, each interacted with sex. Women with high coping motives reported lower post-cue relief craving relative to men, regardless of cue type (B = −0.468, SE = 0.137, $p = 0.001$) (see Table 4 and Figure 5), and men with high enhancement motives reported higher reward craving relative to women, regardless of cue type (B = −0.602, SE = 0.268, $p = 0.025$) (see Table 4 and Figure 5). Finally, there was an enhancement motives × sex interaction predicting post-cue relief craving. Women with high enhancement motives reported lower post-cue relief craving relative to men (B = −0.578, SE = 0.232, $p = 0.013$) (see Table 5 and Figure 5).

Discussion

The goal of the current study was to better understand the relationship between cannabis use motives and valence-specific cannabis craving in a sample of emerging adults who frequently use cannabis. We address some gaps in the literature by exploring the relationship between trait-level motives for cannabis use and transient cannabis craving reactivity, as well as sex/gender differences in these relationships. Importantly, this exploration may inform cannabis interventions for emerging adults who frequently use cannabis and may be at risk for or in the early stages of CUD. For example, both women with high coping motives and men with high enhancement motives may benefit from strategies targeting *reward*-centric craving experiences, despite differences in the prevailing motives.

As expected, cannabis cues consistently produced elevated craving relative to neutral cues, extending prior CREMA findings from tobacco/cigarette use to cannabis use (Tomko et al., 2020; Warthen & Tiffany, 2009; Wray et al., 2015). Somewhat consistent with our hypotheses based in the motivational model (Cooper, 1994; Cox & Klinger, 1988) and theories of craving (Heishman et al., 2009; Jellinek et al., 1955; Ludwig & Wikler, 1974; Marlatt, 1978; Wise, 1988), motives interacted with cue type to predict craving reactivity; however, not in the way we expected. The approach motive we focused on, *enhancement*, was associated with greater relief craving reactivity to cannabis cues relative to neutral cues, and the avoidance motive, *coping*, was associated with greater reward craving reactivity to cannabis cues, in women especially. The current sample was characterized by frequent past month use (~24 days) and high endorsement of enhancement motives which is consistent with prior literature (Bresin & Mekawi, 2019; Espinosa et al., 2022). In addition, approximately 94% of the current sample met criteria for a CUD. Given that

cannabis products are containing higher and higher concentrations of THC and that THC is considered the main psychoactive component associated with addiction (Arterberry et al., 2019; ElSohly et al., 2016), it is possible that this could be indicative of a tendency to experience withdrawal-like craving (i.e., craving characterized by a desire to reduce feelings of anxiety/tension associated with withdrawing from cannabis) in response to cannabis cues (see Wise, 1988).

Coping motives were less frequently endorsed relative to enhancement motives. Considering that the average severity for depression, anxiety, and stress symptoms were in the 'normal' range for the current sample, lower endorsement of coping motives is not surprising. However, in line with some prior research that demonstrated stronger associations between coping motives and cannabis use related problems in women (Bujarski et al., 2012; Simons et al., 1998), the current study observed a stronger association between coping motives and reward craving reactivity to cannabis cues in women. Reward craving has typically been associated with more recreational use (Heishman et al., 2001, 2009), which seems to be characteristic of the current study sample; however, it was somewhat unexpected for it to be associated with greater coping motives. Despite this, these findings are somewhat consistent with a recent laboratory cannabis cue-reactivity paradigm study using a sample of individuals with a trauma history who use cannabis. Reward craving was elevated following cannabis cues as well as trauma cues, relative to neutral cues, indicating a desire to experience the positive effects of cannabis after exposure to either cue (Romero-Sanchiz et al., 2022). For the current study, this could suggest that coping motives for cannabis use are not exclusively avoidance-based and that there is desire for the experience of its positive effects as well.

Similar to our hypotheses regarding the interaction between motives and cannabis cue reactivity, motives interacted with sex/gender to predict post-cue craving (that is, craving after exposure to either cannabis or neutral cues, and not considered "reactivity"), but not quite in the way we expected. Whereas men with high enhancement motives reported high post-cue reward craving, women with high coping motives actually reported less post-cue relief craving relative to women with low coping motives. In combination with the results from the coping motives model predicting reward craving reactivity, it would seem that the current study sample of emerging adult women who use cannabis recreationally were less likely to report relief craving following any cue exposure, even when they have reported higher coping motives overall. That is, trait-level coping motives are not necessarily represented in moment-level craving experiences, and this could be sex/gender specific. This is generally inconsistent with prior research on the relationship between coping motives and related use problems (Bujarski et al., 2012; Simons et al., 1998) and cannabis craving reactivity (Buckner et al., 2011; Garavan, 2010; Naqvi et al., 2014) in women. Alternatively, our findings with respect to emerging adult men and enhancement motives were consistent with prior research showing that emerging adult men were more likely to endorse high enhancement motives (Espinosa et al., 2022).

Unlike some previous studies (Buckner et al., 2012; Espinosa et al., 2022), we did not observe any significant sex/gender differences in cannabis use motives endorsed at baseline. However, some prior studies have reported sex/gender differences in the relationships

between cannabis use motives and other cannabis related outcomes, more so than in the frequency of motives endorsement (Buckner et al., 2012; Bujarski et al., 2012; Morris & Buckner, 2023; Simons et al., 1998). For example, in women, coping motives have been associated with greater cannabis use and are implicated in the relationship between distress tolerance and cannabis related problems (Bujarski et al., 2012; Simons et al., 1998). Given that research seems to suggest there is more a difference in relationships between cannabis use motives and related outcomes by sex/gender, beyond just the endorsement of motives, epistemic gains could be made from future research that focuses on exploring the relationships more closely and incorporating both sex and gender related factors (Coen & Banister, 2012; Heidari et al., 2016).

Limitations

Despite the methodological strengths of using CREMA to examine between- and within-participant effects on variability in reactivity to moment-level cues, our sample was small and racially and ethnically homogenous, which is not representative of the general population nor of the population of emerging adults who frequently use cannabis. This limits the generalizability of our findings. Our sample was also characterized by having a restricted age range (18–21 by design), being non-treatment-seeking, and nearly exclusively meeting criteria for CUD (~94%). These characteristics may have limited the variability in several factors, including length of experience using cannabis which could affect the intensity of craving and motives for use observed. For example, recent frequent use could be more associated with enhancement or expansion motives whereas long-term frequent use could be more associated with coping motives. Indeed, in our sample of young individuals with relatively short cannabis use histories, enhancement motives were endorsed more, on average, relative to other motives.

The CREMA app required an iOS operating system which may have had unintended biasing effects on the portion of our sample that was remote-only (e.g., self-selecting in/out of the study). In fact, there is data suggesting that iPhone users are demographically and characterologically different from other device users (Shaw et al., 2016). However, only about 13% of the sample was remote. As the study was initially designed to detect differences in cannabis use problems across groups characterized by high/low cue reactivity, there was not an intention or expectation to have the power to detect sex/gender differences. Thus, we emphasize caution in the interpretation of our findings. Further, because participants selected the 2-hour blocks in which prompts could be delivered, CREMA sessions were not administered completely at random; however, this strategy may have facilitated increased participant responding, reducing the likelihood of missing data. Finally, as presented in a previous study using this same sample (see Gex et al., 2022), CREMA session length varied widely and may have been the result of random responding or inattention. However, the fidelity checks included in each CREMA session would be expected to reduce the potential for unreliable responses in the analyses.

Conclusions

To our knowledge, this was the first study to closely explore the relationship between cannabis use motives (coping and enhancement) and cannabis craving valence (relief

and reward) using novel CREMA methodology. Enhancement and coping are the most frequently endorsed cannabis use motives in emerging adults, and both motives and craving are highly relevant targets for intervention associated with the maintenance of cannabis use and the development of use related problems, including CUD. Moreover, there are sex/gender differences in these phenomena and their relationships with other cannabis related outcomes that are important to consider in the assessment and intervention of frequent cannabis use and related problems. The current study further emphasizes the need for considering these differences in relation to not only the valence of cannabis use motives but also the valence of cannabis craving. That is, it may not be enough to address enhancement or coping motives alone. Particularly in emerging adults who frequently use cannabis for recreational purposes, there may also be a need to draw attention to craving experiences, considering that there is a potential disconnect or inconsistency between perceived reasons for use and desires to use in the moment. Although the study has important limitations to consider, a high level of precision is key to understanding, assessing, and ultimately intervening in frequent cannabis use to prevent the development of CUD or other cannabis related harms. In particular, this research can inform the development of cannabis brief interventions that target cannabis use motives by acknowledging that endorsement of certain motives in session may not necessarily represent congruent desires/urges to use cannabis in daily life, that they may differ by sex/gender, and that different types of craving may require different strategies or approaches to manage them in the moment.

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References

Adler NE, Epel ES, Castellazzo G, & Ickovics JR (2000). Relationship of subjective and objective social status with psychological and physiological functioning: Preliminary data in healthy, white women. Health Psychology, 19(6), 586–592. 10.1037/0278-6133.19.6.586 [PubMed: 11129362]

Arterberry BJ, Treloar Padovano H, Foster KT, Zucker RA, & Hicks BM (2019). Higher average potency across the United States is associated with progression to first cannabis use disorder symptom. Drug and Alcohol Dependence, 195, 186–192. 10.1016/j.drugalcdep.2018.11.012 [PubMed: 30573162]

Blevins CE, Abrantes AM, Anderson BJ, Caviness CM, Herman DS, & Stein MD (2018). A longitudinal evaluation of the role of alcohol self-concept in alcohol use, motives, negative affect, and alcohol-related problems among emerging adults: Alcohol Self-Concept Among Emerging Adults. The American Journal on Addictions, 27(6), 501–508. 10.1111/ajad.12768 [PubMed: 30039892]

Blevins CE, Banes KE, Stephens RS, Walker DD, & Roffman RA (2016). Change in motives among frequent cannabis-using adolescents: Predicting treatment outcomes. Drug and Alcohol Dependence, 167, 175–181. 10.1016/j.drugalcdep.2016.08.018 [PubMed: 27577862]

Bresin K, & Mekawi Y (2019). Do marijuana use motives matter? Meta-analytic associations with marijuana use frequency and problems. Addictive Behaviors, 99, 106102. 10.1016/j.addbeh.2019.106102 [PubMed: 31473571]

Buckner JD, Silgado J, & Schmidt NB (2011). Marijuana craving during a public speaking challenge: Understanding marijuana use vulnerability among women and those with social anxiety

disorder. Journal of Behavior Therapy and Experimental Psychiatry, 42(1), 104–110. 10.1016/j.jbtep.2010.07.005 [PubMed: 20797696]

Buckner JD, Zvolensky MJ, & Schmidt NB (2012). Cannabis-related impairment and social anxiety: The roles of gender and cannabis use motives. Addictive Behaviors, 37(11), 1294–1297. 10.1016/j.addbeh.2012.06.013 [PubMed: 22766487]

Bujarski S, MacKillop J, & Ray LA (2012). Understanding naltrexone mechanism of action and pharmacogenetics in Asian Americans via behavioral economics: A preliminary study. Experimental and Clinical Psychopharmacology, 20(3), 181–190. 10.1037/a0027379 [PubMed: 22429255]

Center for Behavioral Health Statistics and Quality. (2021). Results from the 2020 National Survey on Drug Use and Health: Detailed tables [Data Table]. Substance Abuse and Mental Health Services Administration. https://www.samhsa.gov/data/

Chabrol H, Ducongé E, Casas C, Roura C, & Carey KB (2005). Relations between cannabis use and dependence, motives for cannabis use and anxious, depressive and borderline symptomatology. Addictive Behaviors, 30(4), 829–840. 10.1016/j.addbeh.2004.08.027 [PubMed: 15833585]

Coen S, & Banister E (Eds.). (2012). What a difference sex and gender make: A gender, sex, and health research casebook. Canadian Institutes of Health Research.

Comeau N, Stewart SH, & Loba P (2001). The relations of trait anxiety, anxiety sensitivity, and sensation seeking to adolescents' motivations for alcohol, cigarette, and marijuana use. Addictive Behaviors, 26(6), 803–825. 10.1016/S0306-4603(01)00238-6 [PubMed: 11768546]

Cooper M (1994). Motivations for alcohol use among adolescents: Development and validation of a four-factor model. Psychological Assessment, 6, 117–128. 10.1037/1040-3590.6.2.117

Cox WM, & Klinger E (1988). A motivational model of alcohol use. Journal of Abnormal Psychology.

Daniel R, & Pollmann S (2014). A universal role of the ventral striatum in reward-based learning: Evidence from human studies. Neurobiology of Learning and Memory, 114, 90–100. 10.1016/j.nlm.2014.05.002 [PubMed: 24825620]

Davis CN, Gex KS, Squeglia LM, Trull TJ, McCarthy DM, Gray KM, McRae-Clark AL, & Tomko RL (under review). Development and initial validation of a momentary cannabis craving scale using multilevel factor analysis.

ElSohly MA, Mehmedic Z, Foster S, Gon C, Chandra S, & Church JC (2016). Changes in cannabis potency over the last 2 decades (1995–2014): Analysis of current data in the United States. Biological Psychiatry, 79(7), 613–619. 10.1016/j.biopsych.2016.01.004 [PubMed: 26903403]

Enders CK (2010). Applied missing data analysis (pp. xv, 377). Guilford Press.

Espinosa A, Ruglass LM, Conway FN, Jackson KM, & White HR (2022). Motives, frequency, and consequences of cannabis use among college students. Journal of Drug Issues, 00220426221093608. 10.1177/00220426221093608

Farmer RF, Kosty DB, Seeley JR, Duncan SC, Lynskey MT, Rohde P, Klein DN, & Lewinsohn PM (2015). Natural course of cannabis use disorders. Psychological Medicine, 45(1), 63–72. 10.1017/S003329171400107X [PubMed: 25066537]

Farris SG, Metrik J, Bonn-Miller MO, Kahler CW, & Zvolensky MJ (2016). Anxiety sensitivity and distress intolerance as predictors of cannabis dependence symptoms, problems, and craving: The mediating role of coping motives. Journal of Studies on Alcohol and Drugs, 77(6), 889–897. 10.15288/jsad.2016.77.889 [PubMed: 27797690]

Garavan H (2010). Insula and drug cravings. Brain Structure and Function, 214(5), 593–601. 10.1007/s00429-010-0259-8 [PubMed: 20512373]

Gex KS, Gray KM, McRae-Clark AL, Saladin ME, & Tomko RL (2022). Distress tolerance and reactivity to negative affective cues in naturalistic environments of cannabis-using emerging adults. Drug and Alcohol Dependence, 238, 109588. 10.1016/j.drugalcdep.2022.109588 [PubMed: 35932750]

Gibbons RD, Hedeker D, & DuToit S (2010). Advances in analysis of longitudinal data. Annual Review of Clinical Psychology, 6, 79–107. 10.1146/annurev.clinpsy.032408.153550

Gray KM, LaRowe SD, & Upadhyaya HP (2008). Cue reactivity in young marijuana smokers. Psychology of Addictive Behaviors, 22(4), 582–586. 10.1037/a0012985 [PubMed: 19071985]

Heidari S, Babor TF, De Castro P, Tort S, & Curno M (2016). Sex and gender equity in research: Rationale for the SAGER guidelines and recommended use. Research Integrity and Peer Review, 1(1), 2. 10.1186/s41073-016-0007-6 [PubMed: 29451543]

Heishman SJ, Evans RJ, Singleton EG, Levin KH, Copersino ML, & Gorelick DA (2009). Reliability and validity of a short form of the Marijuana Craving Questionnaire. Drug and Alcohol Dependence, 102(1), 35–40. 10.1016/j.drugalcdep.2008.12.010 [PubMed: 19217724]

Heishman SJ, Singleton EG, & Liguori A (2001). Marijuana Craving Questionnaire: Development and initial validation of a self-report instrument. Addiction, 96(7), 1023–1034. 10.1046/j.1360-0443.2001.967102312.x [PubMed: 11440613]

Henry EA, Kaye JT, Bryan AD, Hutchison KE, & Ito TA (2014). Cannabis cue reactivity and craving among never, infrequent, and heavy cannabis users. Neuropsychopharmacology, 39(5), Article 5. 10.1038/npp.2013.324 [PubMed: 23800968]

Jellinek EM, Isbell H, Lundquist G, Tiebout HM, Duchêne H, Mardones J, & MacLeod LD (1955). The “craving” for alcohol: A symposium by members of the WHO Expert Committees on Mental Health and on Alcohol. Quarterly Journal of Studies on Alcohol, 16(1), 34–66. 10.15288/qjsa.1955.16.034 [PubMed: 14372009]

Jones A, Remmerswaal D, Verveer I, Robinson E, Franken IHA, Wen CKF, & Field M (2019). Compliance with ecological momentary assessment protocols in substance users: A meta-analysis. Addiction, 114(4), 609–619. 10.1111/add.14503 [PubMed: 30461120]

Karoly HC, Schacht JP, Meredith LR, Jacobus J, Tapert SF, Gray KM, & Squeglia LM (2019). Investigating a novel fMRI cannabis cue reactivity task in youth. Addictive Behaviors, 89, 20–28. 10.1016/j.addbeh.2018.09.015 [PubMed: 30243035]

Koob GF, & Volkow ND (2010). Neurocircuitry of addiction. Neuropsychopharmacology, 35(1), 217–238. 10.1038/npp.2009.110 [PubMed: 19710631]

Lang PJ, Bradley MM, & Cuthbert BN (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. (Technical Report A-8). University of Florida.

Lovibond PF, & Lovibond SH (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. Behaviour Research and Therapy, 33(3), 335–343. 10.1016/0005-7967(94)00075-U [PubMed: 7726811]

Ludwig AM, & Wikler A (1974). “Craving” and relapse to drink. Quarterly Journal of Studies on Alcohol, 35(1), 108–130. 10.15288/qjsa.1974.35.108 [PubMed: 4827273]

Lundahl LH, & Johanson C-E (2011). Cue-induced craving for marijuana in cannabis dependent adults. Experimental and Clinical Psychopharmacology, 19(3), 224–230. 10.1037/a0023030 [PubMed: 21480734]

Marlatt GA (1978). Craving for alcohol, loss of Control, and relapse: A cognitive-behavioral analysis. Alcoholism, 271–314. 10.1007/978-1-4613-2874-2_11 [PubMed: 356648]

Morris PE, & Buckner JD (2023). Cannabis-related problems and social anxiety: The roles of sex and cannabis use motives updated. Addictive Behaviors, 137, 107528. 10.1016/j.addbeh.2022.107528 [PubMed: 36335786]

Múthen LK, & Múthen BO (1998). Mplus User’s Guide. Eighth Edition. (8th Edition.). Muthén & Muthén. https://www.statmodel.com/download/usersguide/MplusUserGuideVer_8.pdf

Naqvi NH, Gaznick N, Tranel D, & Bechara A (2014). The insula: A critical neural substrate for craving and drug seeking under conflict and risk. Annals of the New York Academy of Sciences, 1316(1), 53–70. 10.1111/nyas.12415 [PubMed: 24690001]

Peraza N, Smit T, Garey L, Manning K, Buckner JD, & Zvolensky MJ (2019). Distress tolerance and cessation-related cannabis processes: The role of cannabis use coping motives. Addictive Behaviors, 90, 164–170. 10.1016/j.addbeh.2018.10.047 [PubMed: 30408699]

Romero-Sanchiz P, Mahu IT, Barrett SP, Salmon JP, Al-Hamdani M, Swansburg JE, & Stewart SH (2022). Craving and emotional responses to trauma and cannabis cues in trauma-exposed cannabis users: Influence of PTSD symptom severity. Addictive Behaviors, 125, 107126. 10.1016/j.addbeh.2021.107126 [PubMed: 34655908]

Shaw H, Ellis DA, Kendrick L-R, Ziegler F, & Wiseman R (2016). Predicting smartphone operating system from personality and individual differences. Cyberpsychology, Behavior, and Social Networking, 19(12), 727–732. 10.1089/cyber.2016.0324 [PubMed: 27849366]

Sheehan DV, Lecrubier Y, Sheehan KH, Amorim P, Janavs J, Weiller E, Hergueta T, Baker R, & Dunbar GC (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. J Clin Psychiatry, 59(suppl 20), 22–33.

Simons J, Correia CJ, Carey KB, & Borsari BE (1998). Validating a five-factor marijuana motives measure: Relations with use, problems, and alcohol Motives. Journal of Counseling Psychology, 45(3), 265–273.

Snijders TAB, & Bosker RJ (2011). Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling. SAGE.

Stone AA, & Shiffman S (1992). Reflections on the intensive measurement of stress, coping, and mood, with an emphasis on daily measures. Psychology & Health, 7(2), 115–129. 10.1080/08870449208520014

Stone AA, & Shiffman S (1994). Ecological momentary assessment (EMA) in behavioral medicine. Annals of Behavioral Medicine, 16(3), 199–202. 10.1093/abm/16.3.199

Tiffany ST, & Wray JM (2012). The clinical significance of drug craving. Annals of the New York Academy of Sciences, 1248, 1–17. 10.1111/j.1749-6632.2011.06298.x [PubMed: 22172057]

Tomko RL, Saladin ME, Baker NL, McClure EA, Carpenter MJ, Ramakrishnan VR, Heckman BW, Wray JM, Foster KT, Tiffany ST, Metts CL, & Gray KM (2020). Sex differences in subjective and behavioral responses to stressful and smoking cues presented in the natural environment of smokers. Nicotine & Tobacco Research, 22(1), 81–88. 10.1093/ntr/nty234 [PubMed: 30371887]

Warthen MW, & Tiffany ST (2009). Evaluation of cue reactivity in the natural environment of smokers using ecological momentary assessment. Experimental and Clinical Psychopharmacology, 17(2), 70–77. 10.1037/a0015617 [PubMed: 19331483]

Wise RA (1988). The neurobiology of craving: Implications for the understanding and treatment of addiction. Journal of Abnormal Psychology, 97(2), 118–132. 10.1037/0021-843X.97.2.118 [PubMed: 3290303]

Wray JM, Gray KM, McClure EA, Carpenter MJ, Tiffany ST, & Saladin ME (2015). Gender differences in responses to cues presented in the natural environment of cigarette smokers. Nicotine & Tobacco Research, 17(4), 438–442. 10.1093/ntr/ntu248 [PubMed: 25762753]

Public Health Significance:

This study highlights important sex/gender differences in reasons why emerging adults use cannabis and how these reasons are associated with cravings for cannabis in their daily life. This study also emphasizes the importance of understanding that different types of cravings and reasons for using cannabis exist and that each type may require unique strategies to address them.

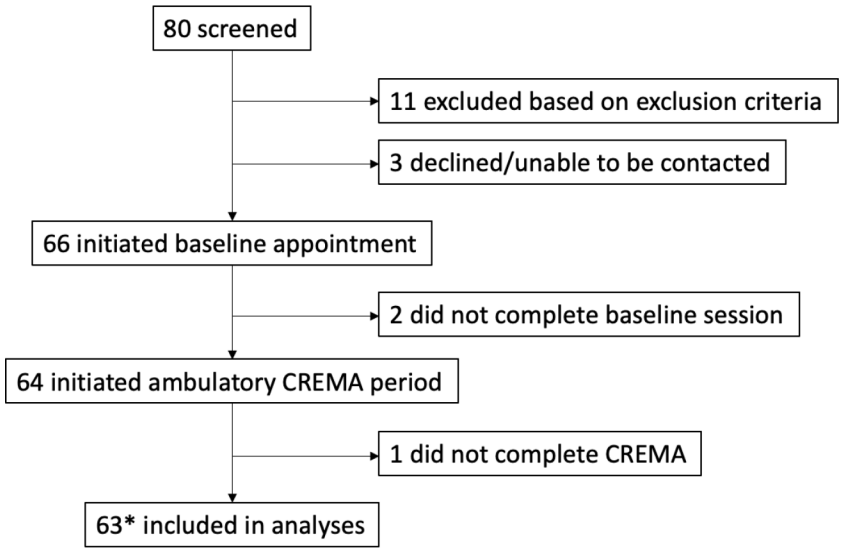

Figure 1.

Flowchart of participant enrollment and activity.

*Only 46 of the 63 were included in final analyses for reward craving because these variables were added later to the study.

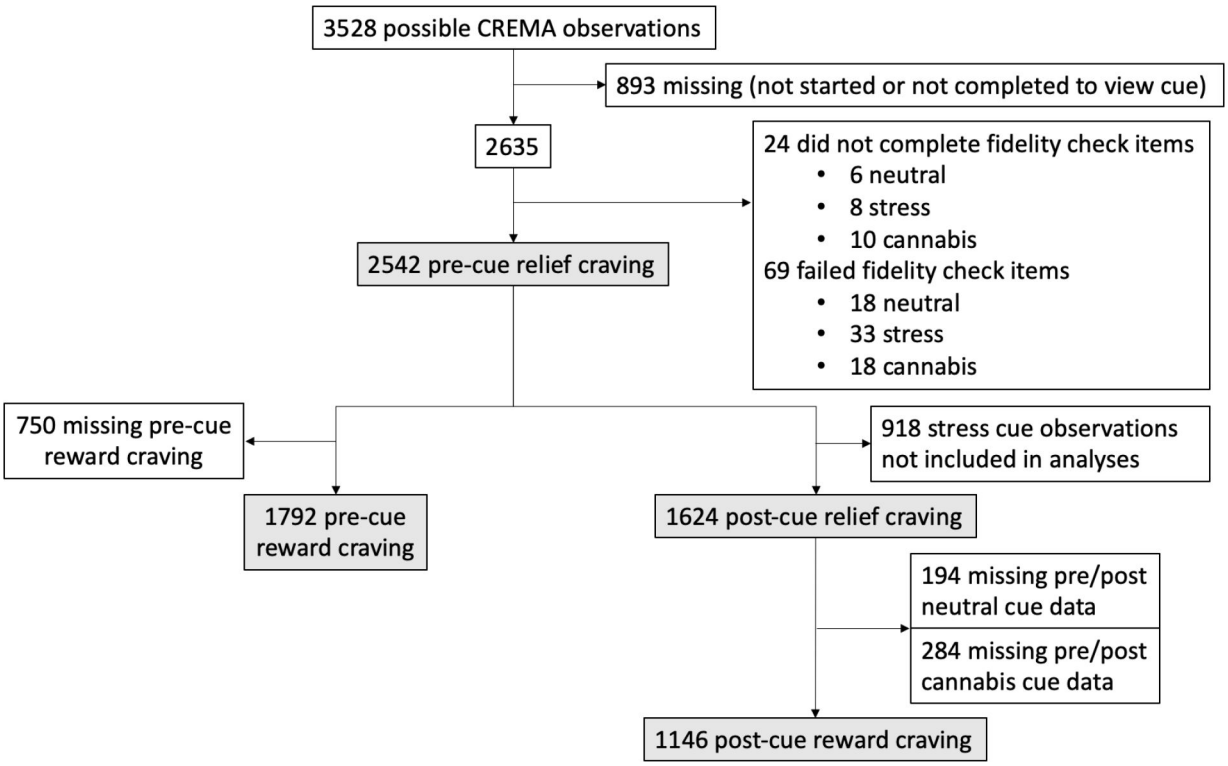

Figure 2.

Flowchart of missing, removed, or excluded CREMA observations. Gray shaded boxes highlight the dependent variables for our models. Because reward craving items were added to the study later, only 46 of the 63 participants received these items, which reduced the total number of pre-cue and post-cue reward craving observations.

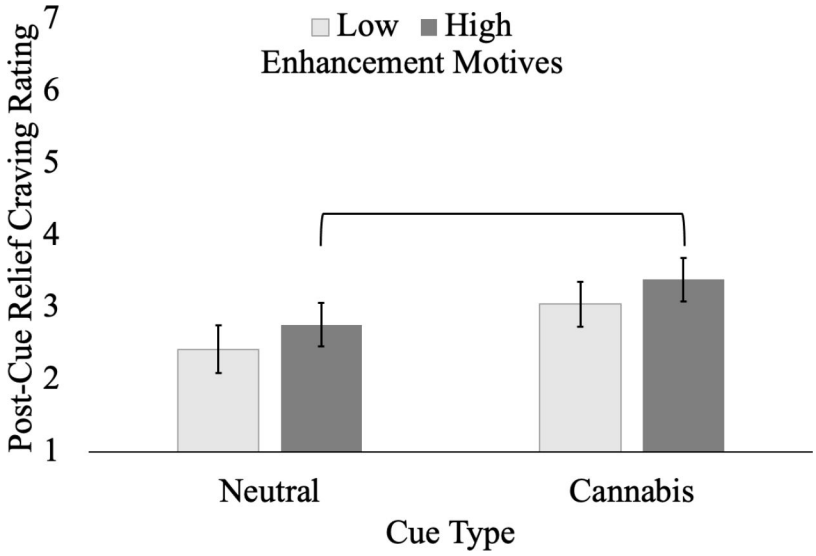

Figure 3.
Enhancement Motives Predicting Relief Craving Reactivity to Cannabis vs. Neutral Cues.

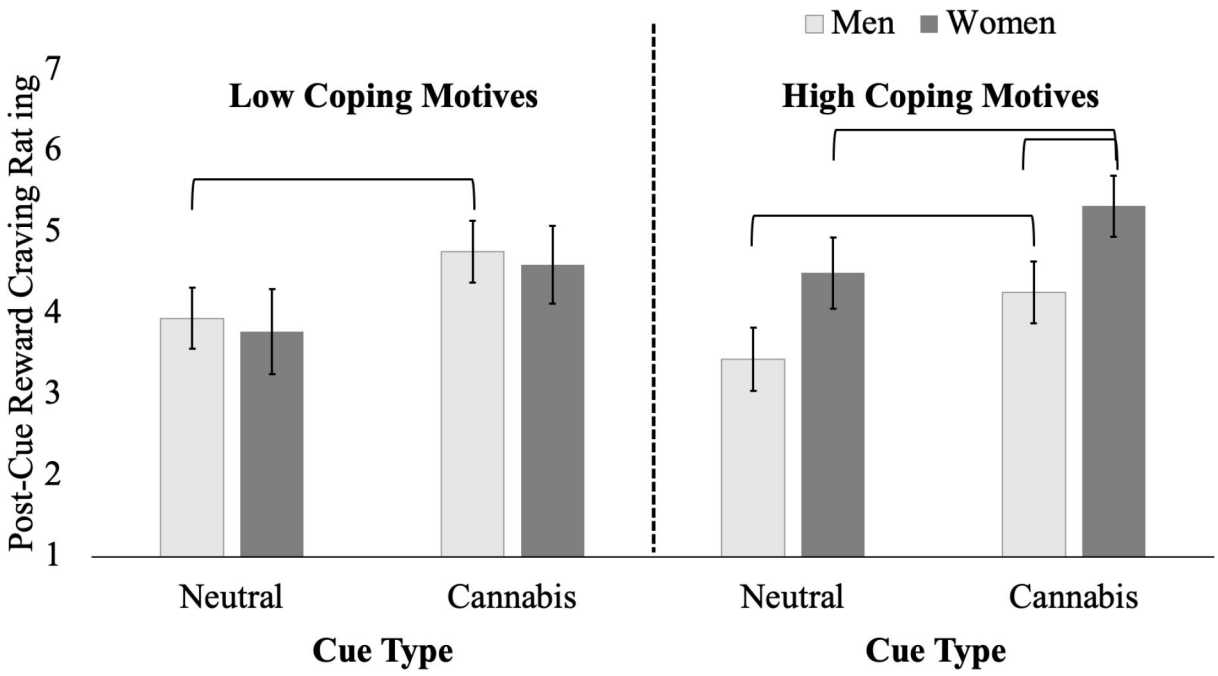

Figure 4.
Three-Way Interaction Between Trait-Level Coping Motives and Sex on Reward Craving Cue Reactivity.

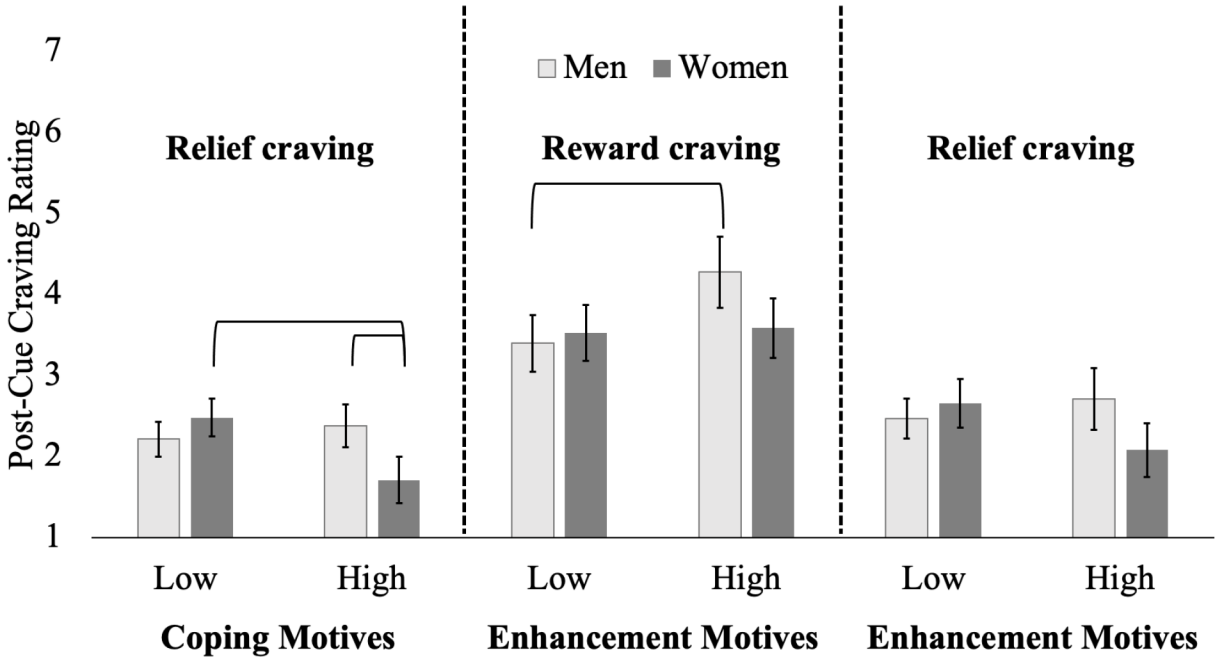

Figure 5.
Sex/Gender × Motives Interactions Predicting Relief and Reward Craving

Table 1

Sample Demographic Characteristics and Cannabis Motives and Craving by Sex

	Full Sample (*N* = 63)	**Women (*n* = 34)**	**Men (*n* = 29)**			
Categorical Variables	***N* (%)**	***N* (%)**	***N* (%)**	**χ^2 (df)**	***p***	***Phi/V***
Race				0.91 (4)	0.92	0.120
Black	4 (6.3%)	2 (5.9%)	2 (6.9%)			
White	54 (85.7%)	29 (85.4%)	25 (86.2%)			
More than one race	1 (1.6%)	1 (2.9%)	0 (0%)			
Unknown/not reported	2 (3.2%)	1 (2.9%)	1 (3.4%)			
Prefer not to answer	2 (3.2%)	1 (2.9%)	1 (3.4%)			
Ethnicity				0.38 (1)	0.54	0.078
Hispanic/Latino	9 (14.3%)	4 (11.8%)	5 (17.2%)			
Not Hispanic/Latino	54 (85.7%)	30 (88.2%)	24 (82.8%)			
Education				6.43 (3)	0.09	0.320
Graduated HS/GED	21 (33.3%)	8 (23.5%)	13 (44.8%)			
Some college	40 (63.5%)	26 (76.5%)	14 (48.3%)			
2-year college	1 (1.6%)	0	1 (3.45%)			
4-year college	1 (1.6%)	0	1 (3.45%)			
Employment				1.88 (4)	0.76	0.173
Student	25 (39.7%)	14 (41.2%)	11 (37.93%)			
Student & employed	28 (44.4%)	16 (47.1%)	12 (41.38%)			
Employed part-time	3 (4.8%)	1 (2.9%)	2 (6.9%)			
Employed full-time	6 (9.5%)	3 (8.8%)	3 (10.34%)			
Unemployed (looking)	1 (1.6%)	0	1 (3.45%)			
CUD Category				0.50 (3)	0.92	0.089
No CUD (0–1)	4 (6.3%)	2 (5.9%)	2 (6.9%)			
Mild (2–3)	13 (20.6%)	8 (23.5%)	5 (17.2%)			
Moderate (4–5)	20 (31.7%)	11 (32.4%)	9 (31.0%)			
Severe (6+)	26 (41.3%)	13 (38.2%)	13 (44.8%)			
Continuous Variables	***M* (*SD*)**	***M* (*SD*)**	***M* (*SD*)**	***t* (df)**	***p***	***d***
Age	19.62 (1.04)	19.62 (0.99)	19.62 (1.12)	0.01 (61)	0.99	0.003
SES community	6.00 (1.50)	5.68 (1.45)	6.38 (1.50)	1.89 (61)	0.06	0.477
SES U.S.	**5.67 (1.61)**	**5.29 (1.40)**	**6.10 (1.74)**	**2.04 (61)**	**0.05**	**0.517**
Baseline Motives						
Coping	2.49 (1.01)	2.61 (0.98)	2.34 (1.04)	−1.05 (61)	0.30	0.265
Enhancement	3.78 (0.71)	3.81 (0.69)	3.75 (0.75)	−0.30 (61)	0.77	0.075
Social	2.57 (0.91)	2.48 (0.83)	2.68 (1.00)	0.87 (61)	0.39	0.219
Expansion	2.57 (1.13)	2.58 (1.17)	2.56 (1.10)	−0.06 (61)	0.95	0.016
Conformity	1.09 (0.17)	1.08 (0.19)	1.09 (0.17)	0.16 (61)	0.87	0.041
Craving [a]						

	Full Sample (*N* = 63)	Women (*n* = 34)	Men (*n* = 29)			
Categorical Variables	***N* (%)**	***N* (%)**	***N* (%)**	**χ^2 (df)**	***p***	***Phi/V***
Emotionality	3.17 (1.45)	3.15 (1.54)	3.20 (1.36)	0.13 (61)	0.90	0.033
Purposefulness	4.70 (1.62)	4.64 (1.57)	4.78 (1.70)	0.35 (61)	0.73	0.089
Expectancy	4.13 (1.46)	4.25 (1.50)	4.00 (1.43)	−0.66 (61)	0.51	0.168
Compulsivity	1.63 (0.81)	1.65 (0.76)	1.61 (0.89)	−0.19 (61)	0.85	0.048
Depressive symptoms [b]	3.95 (3.92)	4.24 (4.55)	3.62 (3.06)	−0.62 (61)	0.54	0.156
Anxiety symptoms [b]	5.29 (4.43)	5.59 (4.82)	4.93 (3.98)	−0.58 (61)	0.56	0.147
Stress symptoms [b]	6.22 (5.11)	6.41 (4.97)	6.00 (5.35)	−0.32 (61)	0.75	0.080
DASS Total score	15.51 (12.70)	16.32 (13.09)	14.55 (10.90)	−0.58 (61)	0.57	0.146
Past-month cannabis use days	25.11 (6.75)	25.59 (6.79)	24.55 (6.78)	−0.60 (61)	0.55	0.153

Note. Other races and ethnicities were asked of participants, however, participants in the current sample only endorsed those listed in the table. Similarly, gender identities were also asked of participants, however, all participants identified as cisgender. The far-right column presents effect sizes for categorical/nominal variables (Phi/Cramer's *V*) and continuous variables (Cohen's *d*).

[a] Scores are from an assessment of craving at the baseline study visit. Due to the way the items are worded, this is considered a "snapshot" of craving experienced in that moment and not intended to represent "trait" or "typical" craving level.

[b] Average scores for each subscale of the DASS-21 in the full sample and by sex/gender were all within the "Normal" ranges (0–9 for the Depression Subscale, 0–7 for the Anxiety Subscale, 0–14 for the Stress Subscale).

Table 2

Bivariate Pearson Correlations Between Trait Level Motives and Cannabis Craving, Use, and Use

Full Sample	**Emotionality**	**Purposefulness**	**Cannabis use**	**CUD**	**Negative**
Coping motives	0.58***	0.31*	0.38**	0.19	0.47***
Enhancement motives	0.47***	0.56**	0.27*	−0.07	0.12
Emotionality craving	-	0.61**	0.29*	0.11	0.49***
Purposefulness craving		-	0.35**	−0.16	0.25
Cannabis use			-	0.06	0.25*
CUD				-	0.29*
Men					
Coping motives	0.52**	0.34	0.39*	0.02	0.51**
Enhancement motives	0.60***	0.71***	0.45*	−0.19	0.23
Emotionality craving	-	0.64***	0.35	0.22	0.65***
Purposefulness craving		-	0.59***	−0.17	0.39*
Cannabis use			-	−0.06	0.30
CUD				-	0.15
Women					
Coping motives	0.65***	0.30	0.35*	0.33	0.44*
Enhancement motives	0.37*	0.43*	0.10	0.02	0.02
Emotionality craving		0.59***	0.25	0.04	0.39*
Purposefulness craving			0.14	−0.16	0.15
Cannabis use				0.15	0.22
CUD					0.38*
Effect Sizes for Differences in Correlations in Men and Women (Cohen's q)					
	Emotionality	Purposefulness	Cannabis use	CUD	Negative
Coping motives	0.199	0	0	0.323	0
Enhancement motives	0.305	0.427	0.384	0.172	0.214
Emotionality craving	-	0	0.110	0.184	0.363
Purposefulness craving		-	0.537	0	0.261
Cannabis use			-	0	0
CUD				-	0.249

Note. Cannabis use = number of use days in the past 30 (per TLFB). CUD = number of criteria met for cannabis use disorder. Emotionality and purposefulness craving were assessed at the baseline study visit. Due to the way the items are worded, this is considered a "snapshot" of craving experienced in that moment and not intended to represent "trait" or "typical" craving level.

*** $p < 0.001$.

** $p < 0.01$.

$^{*}p < 0.05$.

Effect sizes are 0 = no effect, 0.1 – 0.2 = small, 0.3 – 0.4 = medium, 0.5+ = large.

Table 3

Trait-Level Cannabis Use Motives at Baseline Predicting Tonic Craving

	Unstandardized B (SE)	*p*-value	ICC
Tonic Relief Craving			0.680
Coping	0.334 (0.218)	0.126	
Enhancement	1.016 (0.186)	<0.001	
Social	0.129 (0.211)	0.540	
Expansion	0.038 (0.168)	0.819	
Conformity	0.212 (0.917)	0.818	
Tonic Reward Craving			0.600
Coping	0.067 (0.234)	0.775	
Enhancement	1.188 (0.241)	<0.001	
Social	−0.034 (0.220)	0.877	
Expansion	0.082 (0.170)	0.629	
Conformity	−1.124 (1.090)	0.302	

Note. 'Tonic' refers to craving present prior to the presentation of the image cue. There were 2541 observations for tonic relief craving across 63 participants with an average 40 observations per participant. There were 1792 observations for tonic reward craving across 46 participants with an average of 39 observations per participant. All models included session (relative time of day) and time since last use as level 1 (within-participant) covariates, and sex/gender, negative affect, and past 30-day use frequency (# of days) as level 2 (between-participant) covariates. ICC = intraclass correlation coefficient.

Table 4

Motives Predicting Valence-Congruent Post-Cue Craving

Coping Motives predicting Relief Craving				
	Unstandardized B (SE)	**p-value**	**BIC**	**ICC**
Main effects			4142.967	0.629
L1 Random Slopes (n=1624)				
Cue type	0.623 (0.084)	<0.001		
Time since last use	−0.002 (0.049)	0.969		
Session (relative time of day)	0.020 (0.019)	0.310		
Pre-cue person-mean-centered emotionality craving	0.563 (0.041)	<0.001		
Between-Participant Level Fixed Effects (n=63)				
Coping motives	−0.147 (0.070)	0.036		
Sex	−0.198 (0.133)	0.137		
Negative affect	−0.005 (0.006)	0.452		
Past 30-day use frequency	0.013 (0.009)	0.146		
Pre-cue grand-mean-centered emotionality craving	0.803 (0.058)	<0.001		
Interaction Effects				
Sex x coping motives	−0.468 (0.137)	0.001	4139.041	
Enhancement Motives predicting Reward Craving				
	Unstandardized B (SE)	**p-value**	**BIC**	**ICC**
Main effects			3368.275	0.532
L1 Random Slopes (n=1146)				
Cue type	1.139 (0.133)	<0.001		
Time since last use	−0.042 (0.098)	0.666		
Session (relative time of day)	0.074 (0.021)	<0.001		
Pre-cue person-mean centered purposefulness craving	0.505 (0.050)	<0.001		
Between-Participant Level Fixed Effects (n=46)				
Enhancement motives	0.216 (0.163)	0.185		
Sex	−0.307 (0.203)	0.130		
Negative affect	−0.002 (0.008)	0.816		
Past 30-day use frequency	−0.015 (0.016)	0.336		
Pre-cue grand-mean-centered purposefulness craving	0.784 (0.078)	<0.001		
Interaction Effects				
Sex x enhancement motives	−0.602 (0.268)	0.025	3371.711	

Note. Cue type is Neutral = 0, Cannabis = 1. Time since last use is ‘within the last hour’ = 0, ‘more than 1 hour ago’ = 1. Session (relative time of day) ranges from 1 – 4, 1 = beginning of participant’s day, 4 = end of participant’s day. Sex is male = 0, female = 1. Past 30-day use frequency was number of days. BIC = Bayesian Information Criteria. BIC values should not be used to compare non-nested. ICC = intraclass correlation coefficient.

Table 5

Motives Predicting Valence-Incongruent Post-Cue Craving

Enhancement Motives predicting Relief Craving				
	Unstandardized B (SE)	**p-value**	**BIC**	**ICC**
Main effects			4145.158	0.629
L1 Random Slope Means (n=1624)				
Cue type	0.625 (0.084)	<0.001		
Time since last use	0.002 (0.048)	0.962		
Session (relative time of day)	0.020 (0.019)	0.298		
Pre-cue person-mean centered emotionality craving	0.563 (0.041)	<0.001		
Between-Participant Level (n = 63)				
Enhancement motives	−0.091 (0.108)	0.400		
Sex	−0.221 (0.139)	0.112		
Negative affect	−0.009 (0.007)	0.158		
Past 30-day use frequency	0.010 (0.010)	0.350		
Pre-cue grand-mean-centered emotionality craving	0.805 (0.060)	<0.001		
Interactions			4148.076	
Sex x enhancement motives	−0.578 (0.232)	0.013		
Cue x enhancement motives	0.240 (0.115)	0.037		
Coping Motives predicting Reward Craving				
	Unstandardized B (SE)	**p-value**	**BIC**	**ICC**
Main effects			3369.397	0.532
L1 Random Slope Means (n=1146)				
Cue type	1.139 (0.134)	<0.001		
Time since last use	−0.036 (0.098)	0.714		
Session (relative time of day)	0.074 (0.021)	<0.001		
Pre-cue person-mean centered purposefulness craving	0.506 (0.050)	<0.001		
L2 Fixed Effects (n = 46)				
Coping motives	0.050 (0.088)	0.572		
Sex	−0.351 (0.213)	0.100		
Negative affect	−0.005 (0.008)	0.546		
Past 30-day use frequency	−0.012 (0.016)	0.452		
Pre-cue grand-mean-centered purposefulness craving	0.833 (0.066)	<0.001		
Interactions				
Cue x coping x sex	0.613 (0.211)	0.004	3382.404	

Note. Cue type is Neutral = 0, Cannabis = 1. Time since last use is ‘within the last hour’ = 0, ‘more than 1 hour ago’ = 1. Session (relative time of day) ranges from 1 – 4, 1 = beginning of participant’s day, 4 = end of participant’s day. Sex is male = 0, female = 1. Past 30-day use frequency was number of days. BIC = Bayesian Information Criteria. BIC values should not be used to compare non-nested. ICC = intraclass correlation coefficient.