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Is Cannabis Use Associated with Various Indices of Motivation among Adolescents?

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Abstract

Decreased motivation is often noted as a consequence of cannabis use (CU). Previous work has yielded mixed findings, relied mostly on adult samples, and varied to the extent that it accounted for potential confounds. This study examines associations between CU and several motivation indices among adolescents. We hypothesized that regular cannabis users would report lower motivation than light users, and that greater lifetime and past 30-day CU amounts would be associated with decreased motivation. Participants were 79 adolescents, ages 14–18, classified as recent regular cannabis users ($n=36$) or light users ($n=43$). Frequency and amount of substance use were assessed across participants' lifetime and during the past 30 days. Motivation was measured through the Apathy Evaluation Scale (AES) and Motivation and Engagement Scale (MES). To examine associations between CU and our motivation indices, we conducted a series of 2-step hierarchical multiple regressions. Variables found to correlate with any motivation measure were entered on step 1 (e.g. mental health, other substance use) and the relevant CU variable was entered on Step 2. After controlling for confounds, no significant differences were observed between regular and light users on any motivation index, $ps > .01$. Similarly, no associations between motivation and lifetime or past 30-day CU amount were observed, $ps > .01$. Our findings do not support a link between reduced motivation and CU among adolescents after controlling for

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Declaration of Interest

The authors report no conflicts of interest.

relevant confounds. Future studies will examine the levels of CU which influence motivation in adolescents, and the conditions under which this link becomes manifest.

Keywords

cannabis, motivation, adolescence, apathy

Introduction

Cannabis is one of the most commonly used drugs in the United States, with 8.4% of those aged 12 and older reporting current use (Center for Behavioral Health Statistics and Quality (CBHSQ), 2015). It is also frequently used among adolescents. In 2013, approximately 40% of high school seniors reported cannabis use (CU) in the past year (Johnston, Miech, Bachman, & Schulenberg, 2014). Recent trends to legalize use of cannabis have been accompanied by lower perceived risk of use among adolescents (Johnston et al., 2014; Maxwell & Mendelson, 2016; Miech et al., 2015; Schmidt, Jacobs, & Spetz, 2016). This is concerning, since mounting evidence suggests that long-term or heavy CU initiated during adolescence is associated with increased risk of harmful consequences, which includes increased risk of addiction (Volkow, Baler, Compton, & Weiss, 2014), lower educational attainment (Lynskey & Hall, 2000), neurocognitive impairments (Crane, Schuster, Fusar-Poli, & Gonzalez, 2013; Volkow et al., 2016), declines in IQ (Meier et al., 2012), and diminished life satisfaction (Fergusson & Boden, 2008). However, because most of these studies have focused on the effects of heavy and/or chronic CU, these findings may not apply to younger and/or light users. It is thus important to examine the consequences associated with varying levels of CU.

Another possible consequence of CU that has been raised in the literature is reduced motivation, which is the focus of this study. McGlothlin and West (1968) coined the term “amotivational syndrome” to describe the introversion, passivity, and lack of achievement-orientation displayed by regular adult cannabis users. Kouri, Pope, Yurgelun-Todd, and Gruber (1995) compared college-age daily cannabis smokers to occasional cannabis smokers and found that daily smokers were significantly more likely to agree that CU had impaired their motivation. Lane, Cherek, Pietras, and Steinberg (2005) employed a behavioral measure of motivation in which participants could switch between a work task, which required a systematically increasing number of responses but which resulted in greater monetary rewards, or a non-work task, which required no responses from the participants while still providing monetary rewards. They found that regular adolescent cannabis users switched to a non-work task earlier than controls and derived most of their earnings from this task, even though the work task yielded greater monetary rewards. These differences were still present after controlling for cognitive aptitude, sex, and conduct disorder (Lane et al., 2005). Finally, Looby and Earleywine (2007) surveyed a large adult sample of daily cannabis users and found that those meeting criteria for cannabis dependence reported lower levels of motivation, as measured by a subset of items from the Apathy Evaluation Scale (AES).

Recent neuroimaging research findings suggest a connection between CU and motivation and reveal potential underlying mechanisms. A PET study conducted by Bloomfield, Morgan, Kapur, Curran, and Howes (2014) found that reduced dopamine synthesis capacity in regular cannabis users was associated with more apathy as endorsed on the AES. Another PET study found reduced brain reactivity to dopamine stimulation as well as lower positive emotionality (i.e. reward sensitivity, social potency, motivation) in chronic cannabis users relative to controls (Volkow, Wang, et al., 2014). Together, these findings suggest a plausible biological basis for “amotivational syndrome.”

However, findings are mixed, with a comparable number of studies reporting no association between CU and motivation. For example, Duncan (1987) found no association between history of CU and amotivational syndrome in a college-student sample. Similarly, no differences were observed between heavy, moderate, and occasional cannabis users, either male or female, on behavioral measures of motivation (Mello & Mendelson, 1985; Mendelson, Kuehnle, Greenberg, & Mello, 1976). Foltin et al. (1990) administered marijuana and placebo cigarettes to a small sample of male marijuana users, and found that during cannabis administration, participants spent more time performing a less-preferred task in order to gain access to preferred tasks, suggesting motivated responding was not affected. More recently, Barnwell, Earleywine, and Wilcox (2006) found no evidence of reduced motivation in a large sample of adult daily cannabis users compared to nonusers.

The current study seeks to examine the association between CU and self-reported motivation in a sample of adolescent cannabis users using five indices of motivation, while controlling for relevant substance use and mental health confounds. Motivation is here defined as an umbrella term encompassing the cognitions, emotions, and behaviors involved in the activation, execution, and persistence of goal-directed behavior (Kleinginna & Kleinginna, 1981; Marin, Biedrzycki, & Firinciogullari, 1991). Our study contributes to this growing body of literature in several ways. First, to our knowledge, our sample of adolescents aged 14 to 18 years is the youngest sample studied to date in this regard, which allows us to determine whether the findings from adults generalize to a younger sample. Second, prior studies have varied to the extent that they control for several known or suspected confounds related to motivation or CU (e.g., mental health problems). The current study controls for mental health and other substance use variables, thus better isolating the relationship between CU and motivation. Third, our study assesses multiple aspects of motivation, allowing for a more fine-grained analysis of this complex construct. As in prior studies (Bloomfield et al., 2014; Looby & Earleywine, 2007), we assess motivation with the AES (Marin et al., 1991), but given that this measure was originally developed to assess apathy resulting from brain-related pathology among adults, we also assess motivation with an instrument developed for high-school-aged participants: the Motivation and Engagement Scale (MES) (Liem & Martin, 2012). Overall, we hypothesize that, after controlling for potentially confounding variables, a) regular cannabis users will report lower levels of motivation than light cannabis users, and b) greater amount of lifetime and past 30-day CU will be associated with lower levels of motivation.

Method

Participants

Participants include 79 (53.1% M) adolescent cannabis users ages 14 to 18 years ($M = 16.19$, $SD = 1.08$). Of these, 36 (63.9% M) were recent regular cannabis users (i.e. used cannabis 10 or more times in the past month), and 43 (44.2% M) were light users (i.e., had used cannabis but never 10 or more times in a month). Although there is currently no standard definition for what constitutes a “regular” user; we chose a cutoff of “use 10 or more times in a month” because it presumably reflects a frequency of several times per week, a criterion that has previously been used in the literature (Bloomfield et al., 2014; Lane et al., 2005). Further, our group of light users did not include participants with a history of regular cannabis use. Of the 43 light cannabis users, 16 had no use in the past month, 11 had used once, 6 had used twice, 3 had used three times, 2 had used five times, 4 had used six times, and 1 had used nine times. Participants were primarily of Hispanic/Latino ethnicity (88.6%), and included White (69.6%), Black/African American (8.9%), and Mixed Race (15.2%). Table 1 shows participant demographics, substance use characteristics, and motivation scores by cannabis user group, with groups differing only on substance use variables. Participants were recruited from Miami-Dade County middle and high schools, as well as through flyers posted throughout the community and word-of-mouth referrals.

The sample consisted of a subset of participants from a longitudinal study on decision-making and memory in different trajectories of CU (R01 DA031176, PI: Gonzalez). Participant eligibility for the parent study was determined through phone screens. All participants were between the ages of 14 and 16 at baseline, and were able to read and write English. We excluded those who reported any developmental disorders, birth complications, neurological conditions, or a history of mood, or thought disorder, as well as participants who reported frequent or recent use of drugs other than alcohol, nicotine, or cannabis. We also excluded those whose answers to a subset of items from the Substance Dependence Severity Scale (Miele et al., 2000) were highly suggestive of the presence of an alcohol or CU disorder at the time of screening. For the current study, we included only participants who reported at least some use of cannabis, and who could be categorized as either recent regular or light cannabis users.

Procedures

All study procedures were approved by the Florida International University IRB. We obtained parental consent as well as participant assent for all participants. The parent study involves five measurement waves conducted at 6-month intervals over a 2-year period. Each measurement wave involved the administration of a lengthy and detailed protocol assessing substance use, mental health, and cognitive functioning through a combination of clinical interviews, self-report questionnaires, and neuropsychological tests. Collection of motivation data began 22 months after parent study onset. Therefore, not all participants were able to complete these measures at baseline; some completed these measures at follow-up visits. However, all data for this cross-sectional study were obtained at the same time point within each individual participant.

Measures

Substance use.—The Drug Use History Questionnaire (DUHQ) is a detailed semi-structured interview used to assess frequency and quantity of use of 15 different drug classes over a participant's lifetime (Gonzalez et al., 2004; Rippeth et al., 2004). We used frequency and amount (in grams) of CU over the lifetime as well as over the past 30 days. We also used frequency and amount (in drinks and cigarettes, respectively) of alcohol and nicotine use over the lifetime and over the past 30 days as covariates for other substance use in our analyses.

Motivation.

AES. The Apathy Evaluation Scale (AES) is an 18-item self-report questionnaire that defines apathy as a lack of motivation not attributable to diminished level of consciousness, cognitive impairment, or emotional distress (Marin et al., 1991). Reliability (Cronbach's $\alpha = .94$) and validity of this scale have been established (Marin, Firinciogullari, & Biedrzycki, 1993; Marin et al., 1991). Participants responded to each item using a four-point scale (Not At All, Slightly, Somewhat, A Lot). The total apathy score (i.e. sum of scores) was the measure of apathy for our analyses.

MES. The Motivation and Engagement Scale (MES) is a 44-item self-report questionnaire assessing high school students' motivation and engagement (Liem & Martin, 2012). The MES has good reliability (Cronbach's $\alpha = .77-.79$) and validity, and a stable factor structure (Liem & Martin, 2012) among high school students. Participants respond to each item on a 7-point scale, ranging from Strongly Disagree to Strongly Agree. The MES assesses motivation through several "motivation quotients" that allow for a more fine-grained analysis of different aspects of motivation and engagement. The four main quotients are: adaptive cognitive dimensions referred to as "Global Booster Thoughts" (i.e., self-belief, learning focus, valuing school); adaptive behavioral dimensions referred to as "Global Booster Behaviors" (i.e., persistence, task management, planning); maladaptive cognitive dimensions referred to as "Global Mufflers" (i.e., uncertain control, failure avoidance, anxiety); and maladaptive behavioral dimensions referred to as "Global Guzzlers" (i.e., disengagement, self-sabotage) (Liem & Martin, 2012). These four global motivation quotients were included in our analyses as measures of motivation.

Mental health.

DASS-21. We assessed for symptoms of emotional distress with the short version of the Depression, Anxiety, and Stress Scales (DASS-21): a 21-item self-report questionnaire assessing the severity of negative emotional symptoms over the past week (Henry & Crawford, 2005). Reliability (Cronbach's $\alpha = .82-.90$) and validity of the DASS-21 scales have been previously established in adults as well as adolescents (Henry & Crawford, 2005; Szabó, 2010). The depression and anxiety scales z-scores were covariates in our analyses.

C-DISC. The ADHD module of the computerized Diagnostic Interview Schedule for Children (C-DISC; Shaffer et al., 2000) was used to assess for severity of and impairment due to symptoms of ADHD. We used the ADHD symptom count as a covariate in our analyses.

Estimated IQ.: We used the Word Reading subtest of the Wide Range Achievement Test 4 (WRAT4; Wilkinson and Robertson, 2006) to estimate participants' IQs, which we used as covariates in our analyses.

Statistical Analyses

All analyses were conducted in SPSS 23.0. We conducted a series of simple linear regressions to identify potential confounds associated with motivation in our sample to use as covariates in further analyses. We investigated the associations between motivation and several aspects of mental health which have been previously linked to motivation, specifically depression, anxiety, ADHD symptoms (Spielberg et al., 2014; Volkow et al., 2011). We also investigated the relationships between motivation and demographic variables such as sex and age, as well as IQ as an index of overall cognitive ability. Finally, we examined associations between motivation and other substance use, specifically lifetime and past 30-day frequency and amount of alcohol and nicotine use. All variables significantly associated with motivation indices were included as covariates in further analyses. We selected an alpha level of .05 as threshold for statistical significance when identifying covariates to be included in our analyses. Due to the large number of regressions to be conducted, we selected a more conservative alpha level of .01 for all other analyses.

All assumptions associated with linear regression were tested. All regression models conducted to examine our primary hypotheses were hierarchical multiple regressions with 2 steps. This was done in order to determine whether the CU accounted for a significant amount of variance in the given motivation index beyond that accounted for by the covariates. Bootstrapping with 1000 samples was used to make regressions robust to non-normality in the drug use and mental health variables. Outliers were identified as recurring cases with DFBETAS greater than an absolute value of 1. Two outliers were identified for the lifetime amount analyses, and three outliers were identified for the past 30-day amount analyses. Regressions were then rerun after Winsorizing values for these outliers; the results remained the same. All results presented below are those obtained after Winsorizing outliers.

Between-group comparisons.—In order to test the hypothesis that regular cannabis users would report lower levels of motivation than light users, we conducted a series of hierarchical multiple regressions to compare motivation levels between recent regular and light cannabis users. On step 1, we entered all variables previously identified as covariates. On step 2, we entered the comparison between cannabis user groups. Since cannabis user group was based on past 30-day CU frequency, the alcohol and nicotine variables included in these analyses as covariates were those of past 30-day frequency, thus mirroring the cannabis variable. We ran 5 such regressions, using AES total score and the four MES motivation quotients as dependent variables.

Amount of CU and motivation.—In order to test the hypothesis that greater lifetime CU amount would be associated with lower motivation, we conducted a series of hierarchical multiple regressions with all identified covariates entered on step 1, and lifetime CU amount entered on step 2. Substance use covariates included were those of lifetime amount of alcohol and nicotine use. Five such regressions were conducted, with the AES and the four

MES global motivation quotients as dependent variables. In order to test the hypothesis that greater past 30-day CU amount would be associated with lower motivation, this process was then repeated with the past 30-day CU amount variable.

Results

Table 2 displays bivariate correlations between all covariates, substance use variables, and motivation variables. Detailed statistical results are found in Table 3 for between-group analyses, Table 4 for analyses with lifetime CU amount, and Table 5 for past 30-day CU amount.

Identification of Covariates

Sex, IQ, depression, anxiety, ADHD symptoms, lifetime and past 30-day alcohol and nicotine use amount and frequency were significantly associated with at least one of our motivation indices, $ps < .05$. Age was not associated with any of the motivation indices, $ps > .05$. Thus, further analyses included sex, IQ, depression, anxiety, ADHD symptoms, and amount and frequency of lifetime and past 30-day alcohol and nicotine use as covariates.

Differences between Light and Regular Cannabis Users in Motivation

AES.—On step 1, the covariates did not account for a significant amount of variance in AES score, $F(7, 71) = 2.314$, $p = .035$, $R^2 = .186$. Greater past 30-day alcohol use frequency was associated with lower apathy (Table 3). On step 2, the covariates and cannabis user group did not account for a significant amount of variance in AES score, $F(8, 70) = 2.032$, $p = .055$, $R^2 = .188$. There were no significant differences in apathy between recent regular and light cannabis users.

MES-Global Booster Thoughts.—With covariates entered on step 1, the regression model was not significant, $F(7, 71) = 2.013$, $p = .065$, $R^2 = .166$. Greater past 30-day frequency of alcohol use was associated with more adaptive thoughts. When cannabis user group was entered on step 2, the model remained nonsignificant, $F(8, 70) = 1.745$, $p = .103$, $R^2 = .188$. There were no significant between-group differences in Global Booster Thoughts.

MES-Global Booster Behaviors.—On step 1, the covariates did not explain a significant amount of variance in Global Booster Behaviors, though the model approached significance, $F(7, 71) = 2.744$, $p = .014$, $R^2 = .213$. Female sex was associated with more adaptive behaviors. The overall model remained marginally significant when cannabis user group was added on step 2, $F(8, 70) = 2.764$, $p = .010$, $R^2 = .240$. There were no significant differences in Global Booster Behaviors between recent regular and light cannabis users.

MES-Global Mufflers.—On step 1, the covariates did not account for a significant amount of variance in Global Mufflers, $F(7, 71) = 2.657$, $p = .017$, $R^2 = .208$. No coefficients were significant. With cannabis user group entered at step 2, the model continued to approach significance, $F(8, 70) = 2.741$, $p = .011$, $R^2 = .239$. There were no between-group differences in Global Mufflers score.

MES-Global Guzzlers.—The covariates entered at step 1 did not explain a significant amount of variance in Global Guzzlers, $F(7, 71) = 2.714, p = .015, R^2 = .211$. No partial regression coefficients were significant. On step 2, the covariates and cannabis user status together explained an amount of variance in Global Guzzlers that approached significance, $F(8, 70) = 2.793, p = .010, R^2 = .242$. There were no significant between-group differences in Global Guzzlers.

Associations between Amount of Lifetime CU and Motivation

AES.—On step 1, covariates did not account for a significant amount of variance in AES score, $F(7, 71) = 1.739, p = .114, R^2 = .146$. As shown in Table 4, no bootstrapped partial regression coefficients were significant. Lifetime CU amount and the covariates did not account for a significant amount of variance in AES score on step 2, $F(8, 70) = 1.509, p = .170, R^2 = .147$. Furthermore, the coefficient relating lifetime CU amount to AES score was not significant.

MES—Global Booster Thoughts.—The covariates did not account for a significant amount of variance in Global Booster Thoughts when entered on step 1, $F(7, 71) = 1.66, p = .133, R^2 = .141$. No coefficients were significant. Similarly on step 2, the model was not significant, $F(8, 70) = 1.51, p = .170, R^2 = .147$. The partial regression coefficient relating lifetime CU amount to Global Booster Thoughts was not significant.

MES—Global Booster Behaviors.—On step 1, the covariates did not explain a significant amount of variance in Global Booster Behaviors, $F(7, 71) = 2.23, p = .042, R^2 = .180$. Female sex was associated with more adaptive behaviors. On step 2, lifetime CU amount and the covariates did not account for a significant amount of variance, $F(8, 70) = 2.01, p = .058, R^2 = .187$. The partial regression coefficient relating lifetime CU amount to Global Booster Behaviors was not significant.

MES—Global Mufflers.—When entered on step 1, the covariates did not account for a significant amount of variance in Global Mufflers, $F(7, 71) = 2.446, p = .026, R^2 = .194$. There were no significant associations between the covariates and Global Mufflers score. The overall model remained nonsignificant on step 2, $F(8, 70) = 2.456, p = .021, R^2 = .219$. The coefficient relating lifetime CU amount to Global Mufflers was not significant.

MES-Global Guzzlers.—With covariates entered on step 1, the overall model was marginally significant, $F(7, 71) = 2.919, p = .010, R^2 = .223$. However, no partial regression coefficients were significant. With lifetime CU amount added on step 2, the model remained marginally significant, $F(8, 70) = 2.659, p = .013, R^2 = .233$. The partial regression coefficient relating lifetime CU amount to Global Guzzlers was not significant.

Associations between Amount of Recent (Past 30-Day) CU and Motivation

AES.—On step 1, the covariates did not account for a significant amount of variance in AES score, $F(7, 71) = 2.336, p = .033, R^2 = .187$. Lower past 30-day amounts of alcohol were associated with higher apathy scores (Table 5). When past 30-day CU amount was entered on step 2, the model approached significance, $F(8, 70) = 2.595, p = .015, R^2 = .229$.

Furthermore, the partial regression coefficient relating past 30-day CU amount to AES score was not significant.

MES—Global Booster Thoughts.—When the covariates were entered on step 1, the overall model was not significant, $F(7, 71) = 2.293$, $p = .036$, $R^2 = .184$. Greater past 30-day alcohol amounts were associated with higher Global Booster Thoughts scores. On step 2, cannabis and the covariates did not explain a significant amount of variance, $F(8, 70) = 2.012$, $p = .057$, $R^2 = .187$. Past 30-day CU amount was not significantly associated with Global Booster Thoughts.

MES—Global Booster Behaviors.—The covariates explained a significant amount of variance in Global Booster Behaviors, $F(7, 71) = 3.313$, $p = .004$, $R^2 = .184$. Female sex was associated with higher Global Booster Behaviors scores. The overall model remained significant when past 30-day cannabis amount was entered on step 2, $F(8, 70) = 3.842$, $p = .001$, $R^2 = .187$, with the cannabis variable accounting for a marginally significant increase in explained variance, $\mu F(1, 70) = 5.931$, $p = .017$, $\mu R^2 = .059$. The coefficient relating past 30-day CU amount to Global Booster Behaviors was, however, not significant.

MES—Global Mufflers.—On step 1, the covariates did not account for a significant amount of variance, $F(7, 71) = 2.566$, $p = .020$, $R^2 = .202$. No bootstrapped partial regression coefficients were significant. On step 2, the covariates and past 30-day CU amount explained a marginally significant amount of variance in Global Mufflers, $F(8, 70) = 2.732$, $p = .011$, $R^2 = .238$. Past 30-day CU amount was not significantly associated with Global Mufflers score.

MES—Global Guzzlers.—On step 1, the covariates explained a significant amount of variance in Global Guzzlers, $F(7, 71) = 3.122$, $p = .006$, $R^2 = .235$. No coefficients were significant. Similarly, when past 30-day cannabis amount was entered on step 2, the model was significant, $F(8, 70) = 3.240$, $p = .003$, $R^2 = .235$. However, past 30-day CU amount was not significantly associated with Global Guzzlers.

Post-hoc Power Analysis

A post-hoc power analysis was conducted using G*Power 3.1 (Erdfelder, Faul, & Buchner, 1996). Results revealed that with our sample of 79 participants, we achieved sufficient power to detect medium and large effects using a two-tailed alpha level of .01.

Discussion

In this study, we examined the associations between CU and different aspects of motivation in a sample of adolescent cannabis users. After identifying and controlling for potential confounds (i.e., mental health and other substance use), we found no differences in motivation between recent regular cannabis users and light cannabis users. We also found no significant associations between lifetime or past 30-day amount of CU and any of the motivation indices. Furthermore, the cannabis variable did not account for a significant amount of variance beyond that accounted for by the covariates.

We did observe some trends towards significance in the adjusted models, with the associations between past 30-day CU amount and scores on AES, Global Booster Behaviors, Global Mufflers, and Global Guzzlers reaching significance at a more liberal threshold ($\alpha = .05$). Surprisingly, these modest to moderate effects suggested that greater amounts of past 30-day CU were associated with lower apathy, more adaptive behavior, less maladaptive cognition, and less maladaptive behavior, respectively. However, as noted, these results failed to reach statistical significance at our more conservative alpha level of .01. Similarly, the unadjusted models showed significant associations between past 30-day CU and Global Booster Thoughts ($\beta = .17, p = .04$), Global Booster Behaviors ($\beta = .34, p = .001$), and Global Guzzlers ($\beta = -.20, p = .003$), such that greater CU was associated with greater motivation. These effects ranged from small to moderate, and were attenuated with the inclusion of covariates. Taken together, our findings provide no evidence in support of an “amotivational syndrome” or diminished motivation among our sample of adolescent cannabis users as a consequence of their CU.

As previously noted, prior research on CU and motivation has yielded mixed findings. Our results are consistent with those suggesting no strong association. Prior studies have not been consistent in the extent to which they have controlled for several known or potential variables related to motivation. It is therefore possible that the association between CU and motivation in some of those studies could be explained by other factors, such as demographics (Steinmayr & Spinath, 2008), IQ, other substance use, and mental health problems such as symptoms of depression, anxiety, and ADHD (Spielberg et al., 2014; Volkow et al., 2011). Indeed, Musty and Kaback (1995) found that this association could be accounted for by coexisting depressive symptoms in a sample of college students. Of note, depression and anxiety had significant small to moderate negative effects on motivation across several of our analyses. This highlights the importance of controlling for mental health problems, which may simultaneously influence motivation and level of substance use. Furthermore, our observed trends suggesting that greater amounts of past 30-day CU were associated with scores reflecting greater motivation could perhaps be explained by the fact that cannabis may have become a major motivator for many users (Volkow et al., 2016). For instance, studies have found greater activation in reward areas of the brain during exposure to cannabis cues as compared to natural rewards (e.g. food cues), suggesting that cannabis may become a greater motivator than other stimuli, particularly for long-term users (Filbey et al., 2016; Wetherill et al., 2014). Although speculative, it is possible that the self-report of adolescents in our sample reflects an increased motivation to smoke (e.g. a high MQ-Global Booster Behaviors score could reflect an adolescent’s ability to plan his/her homework around his/her CU).

Another possible explanation for these results is the young age of our adolescent sample. Given important developmental changes that take place during adolescence, the adolescent brain may respond differently to the effects of cannabis (Casey & Jones, 2010; Lisdahl, Gilbert, Wright, & Shollenbarger, 2013). The younger age also means that participants have been using cannabis for shorter duration than adults in prior studies. Furthermore, our sample’s median lifetime amount of CU was 60g (range 0.25g to 2,448g), and the median past 30-day amount of CU was only 2.45g (range 0g to 130.50g). These figures suggest that CU is still relatively low for many of the participants in our sample, despite their user status.

Though this was partially addressed by treating CU amount as a continuous, rather than categorical variable, it is possible that the adolescents in our sample have not been using cannabis long enough for effects on motivation to manifest. In any case, in light of the recent aforementioned trends in risk perception in this population (Johnston et al., 2014; Miech et al., 2015), it is imperative that future studies continue to examine the consequences of CU at this developmental stage and how use at this stage affects users in later life.

These findings should be interpreted in light of several limitations. First, our sample size was relatively small. Given the large number of predictors included in our analyses, we did not achieve sufficient power to detect small effects. Thus, while our findings do not support moderate to strong effects of CU on motivation, it is possible that CU has more subtle effects on this construct. Second, motivation is a multi-faceted construct (Ryan & Deci, 2000) which has proven difficult to define (Kleinginna & Kleinginna, 1981). Though our study incorporated measures that aimed to assess multiple aspects of motivation, it is possible that these measures were not optimal for several reasons. For instance, while the AES asked participants to respond to each item according to the degree to which it applied to them over the past 4 weeks, the MES did not specify a timeframe. Therefore, it is difficult to ascertain whether participants' answers to the MES reflect the degree to which a given item applied to them on that particular day or over a longer period of time. Also, like the measures included in many previous studies, the AES and MES assess self-reported motivation. It is possible that if CU indeed influences motivation, self-report measures may be suboptimal. Future studies should complement self-report instruments with behavioral measures of motivation. Although a strength of this study was the inclusion of multiple indices of motivation, there are still many aspects of this complex construct that we did not assess (e.g. intrinsic and extrinsic motivation, achievement motivation, motivation in nonacademic settings). Future studies should strive to develop and/or incorporate more precise measures of motivation. Third, while the racial and ethnic composition of our sample is consistent with that of the greater Miami area from which they were recruited, and we have no reason to believe that the association between cannabis and motivation varies as a function of race, ethnicity or culture, this question should be assessed empirically. Finally, these results are based on cross-sectional analyses of data. Future studies will rely on longitudinal analyses to examine the association between CU and motivation over time. This would be particularly interesting with adolescents, since the effects of CU on the adolescent brain may vary as they continue to develop.

Conclusions

Overall, after controlling for potential confounds, our results do not support a moderate or strong association between CU and decreased motivation in our sample of adolescents. However, given more well-established negative consequences of CU during adolescence, such as declines in IQ, both acute and persistent cognitive impairments (Crane et al., 2013; Meier et al., 2012), lower academic achievement, and an increased likelihood of dropping out of school (Lynskey & Hall, 2000), our findings do not necessarily imply that cannabis effects on motivation at this developmental stage are non-existent. Rather, these effects could be smaller than previous research would suggest. We believe that this link should continue to

be examined in future studies, particularly at varying degrees of CU to determine when and under what conditions it may emerge.

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Table 1.

Participant demographics, substance use characteristics, and motivation scores by cannabis user group.

	Recent Regular Cannabis Users (n = 36)	Light Cannabis Users (n = 43)
	% or <i>M</i> ± <i>SD</i>	% or <i>M</i> ± <i>SD</i>
Demographics		
Age	16.22 ± 1.17	16.16 ± 1.00
% Female	36.11%	55.81%
Estimated FSIQ	107.39 ± 15.67	107.67 ± 13.21
Years of Education	10.06 ± 1.09	9.91 ± 1.15
Substance Use Characteristics		
Age of Onset of CU	13.25 ± 1.40 *	14.16 ± 1.11
Lifetime Amount of Use [Md, IQR]		
<i>Alcohol (drinks)</i>	94.00 [12.50, 324.50] *	28.00 [4.00, 142.00]
<i>Nicotine (cigarettes)</i>	.00 [.00, 18.50]	.00 [.00, 2.50]
<i>Cannabis (grams)</i>	309.00 [138.50, 1070.75] *	8.00 [4.00, 43.00]
<i>Range of CU (grams)</i>	[18.00, 2448.00]	[.25, 284.00]
Past 30-day Amount of Use [Md, IQR]		
<i>Alcohol (drinks)</i>	4.50 [.00, 12.75]	1.00 [.00, 6.50]
<i>Nicotine (cigarettes)</i>	.00 [.00, 1.50] *	.00 [.00, .00]
<i>Cannabis (grams)</i>	14.50 [4.98, 30.00] *	.25 [.00, 1.00]
<i>Range of CU (grams)</i>	[2.45, 130.50]	[.00, 4.50]
Current Cannabis Abuse	44.44% *	4.65%
Current Cannabis Dependence	11.11%	.00%
Motivation Scores		
AES	29.31 ± 6.44	28.86 ± 5.96
MES-Global Booster Thoughts	105.25 ± 10.80	105.09 ± 13.21
MES-Global Booster Behaviors	103.97 ± 14.11	100.42 ± 14.43
MES-Global Muffler	91.72 ± 10.84	94.00 ± 11.20
MES-Global Guzzler	98.00 ± 10.93	100.47 ± 14.51

* Significant between-group difference, $p < .05$ *M* = mean, *SD* = standard deviation, Md = median, IQR = interquartile range

Table 2.

Correlations between variables of interest and covariates.

	AES	MES-Global Booster Thoughts	MES-Global Booster Behaviors	MES-Global Muffler	MES-Global Guzzler	IQ	Sex	Depression +	Anxiety +	ADHD Symptoms +	Lifetime Amount CU +	Lifetime Amount Alcohol +	Lifetime Amount Nicotine +	Past 30-Day Amount CU +	Past 30-Day Amount Alcohol +	Past 30-Day Amount Nicotine +
AES	-															
MES-Global Booster Thoughts	.55**	-														
MES-Global Booster Behaviors	.60**	.64**	-													
MES-Global Muffler	-.02	-.11	-.08	-												
MES-Global Guzzler	.34*	.50**	.45**	.51**	-											
IQ	-.08	-.04	-.05	-.23*	-.05	-										
Sex	-.13	.21	-.34*	.04	-.06	.04	-									
Depression +	.43**	-.23*	-.24*	.05	.44**	.04	.02	-								
Anxiety +	.25*	-.21	-.16	.21	.18	-.10	-.05	.44**	-							
ADHD Symptoms +	.17	-.09	-.05	.15	.30*	-.03	-.16	.40**	.34*	-						
Lifetime Amount CU +	.13	-.02	.06	-.23*	.01	-.15	-.20	.17	.02	.21	-					
Lifetime Amount Alcohol +	-.05	.21	.07	.03	.07	-.02	-.06	.10	-.17	.00	.30*	-				
Lifetime Amount Nicotine +	.05	.09	.07	.02	.16	-.10	.02	.14	.03	-.10	.25*	.33*	-			
Past 30-Day Amount CU +	-.07	.07	.26*	-.12	-.14	-.17	-.12	.00	.11	.13	.80**	.22	.16	-		
Past 30-Day Amount Alcohol +	-.19	.26*	.23*	.21	.09	-.07	.07	.02	-.15	.08	.12	.70**	.20	.25*	-	
Past 30-Day Amount Nicotine +	-.01	.12	.19	.02	-.13	.01	.06	.03	.17	.00	.29*	.18	.69**	.35*	.150	-

** Significant at $p = .001$.

* Significant at $p < .05$

All correlations presented are Pearson's r , except where

+ denotes Spearman's rho due to non-normality of the variables.

Table 3.

Bootstrapped partial regression coefficients for between-group comparisons.

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
IQ	-.118	-.117
Sex	-.165	-.175
ADHD Symptoms	.093	.105
Depression	.355 *	.357 *
Anxiety	-.154	-.156
30 day frequency alcohol	-.256 **	-.255 **
30 day frequency nicotine	.091	.105
Recent regular vs. light users		-.056
<i>MES--Global Booster Thoughts</i>		
IQ	-.016	-.017
Sex	.241 *	.246 *
ADHD Symptoms	.010	.004
Depression	-.166	-.168
Anxiety	.044	.045
30 day frequency alcohol	.296 *	.296 *
30 day frequency nicotine	.110	.103
Recent regular vs. light users		.028
<i>MES--Global Booster Behaviors</i>		
IQ	-.025	-.029
Sex	.363 **	.292
ADHD Symptoms	.005	-.033 **
Depression	-.177	-.185
Anxiety	.030	.038
30 day frequency alcohol	.155	.154
30 day frequency nicotine	.223	.181
Recent regular vs. light users		.177
<i>MES--Global Mufflers</i>		
IQ	-.148	-.143
Sex	.096	.064
ADHD Symptoms	.158	.199
Depression	-.155	-.147
Anxiety	.395 *	.387 *
30 day frequency alcohol	.141	.143
30 day frequency nicotine	-.014	.031
Recent regular vs. light users		-.190

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
<i>MES--Global Guzzlers</i>		
IQ	-.059	-.054
Sex	-.034	-.066
ADHD Symptoms	.267 *	.307 **
Depression	.286	.295
Anxiety	.000	-.008
30 day frequency alcohol	.033	.035
30 day frequency nicotine	-.175	-.130
Recent regular vs. light users		-.189

* significant at $p < .05$ level, uncorrected

** significant at $p < .01$ level, uncorrected

Table 4.

Bootstrapped partial regression coefficients for analyses with lifetime CU amount.

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
IQ	-.129	-.127
Sex	-.175	-.177
ADHD Symptoms	.104	.100
Depression	.359 *	.355 *
Anxiety	-.135	-.135
Lifetime amount alcohol	-.177	-.191
Lifetime amount nicotine	.081	.075
Lifetime amount cannabis		.032
<i>MES--Global Booster Thoughts</i>		
IQ	.015	.022
Sex	.284 *	.278 *
ADHD Symptoms	-.013	-.026
Depression	-.207	-.217
Anxiety	.103	.104
Lifetime amount alcohol	.295 *	.253
Lifetime amount nicotine	.021	.005
Lifetime amount cannabis		.098
<i>MES--Global Booster Behaviors</i>		
IQ	-.007	.000
Sex	.387 **	.382 **
ADHD Symptoms	.013	.000
Depression	-.207	-.217
Anxiety	.063	.063
Lifetime amount alcohol	.071	.029
Lifetime amount nicotine	.193	.177
Lifetime amount cannabis		.097
<i>MES--Global Mufflers</i>		
IQ	-.151	-.164
Sex	.092	.102
ADHD Symptoms	.139	.164
Depression	-.141	-.121
Anxiety	.395 *	.395 *
Lifetime amount alcohol	.073	.155
Lifetime amount nicotine	-.079	-.048
Lifetime amount cannabis		-.192

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
<i>MES--Global Guzzlers</i>		
IQ	-.060	-.068
Sex	-.033	-.027
ADHD Symptoms	.234	.249
Depression	.298	.310
Anxiety	.011	.011
Lifetime amount alcohol	.134	.185
Lifetime amount nicotine	-.232	-.213
Lifetime amount cannabis		-.119

* significant at $p < .05$ level, uncorrected

** significant at $p < .01$ level, uncorrected

Table 5.

Bootstrapped partial regression coefficients for analyses with past 30-day CU amount.

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
IQ	-.138	-.180
Sex	-.175	-.191
ADHD Symptoms	.116	.106
Depression	.341 *	.370 **
Anxiety	-.134	-.122
30 day amount alcohol	-.272 **	-.207 *
30 day amount nicotine	.109	.223
30 day amount cannabis		-.262 *
<i>Global Booster Thoughts</i>		
IQ	-.005	.006
Sex	.251 *	.255 *
ADHD Symptoms	-.022	-.019
Depression	-.150	-.157
Anxiety	.034	.031
30 day amount alcohol	.338 **	.321 **
30 day amount nicotine	.060	.032
30 day amount cannabis		.066
<i>Global Booster Behaviors</i>		
IQ	-.025	.025
Sex	.371 **	.390 **
ADHD Symptoms	-.017	-.005
Depression	-.171	-.204
Anxiety	.035	.020
30 day amount alcohol	.237 *	.159
30 day amount nicotine	.187	.052
30 day amount cannabis		.312 *
<i>Global Mufflers</i>		
IQ	-.141	-.180
Sex	.097	.082
ADHD Symptoms	.136	.126
Depression	-.140	-.114
Anxiety	.407 *	.418 *
30 day amount alcohol	.105	.166
30 day amount nicotine	-.104	.001

<i>AES</i>	<i>Step 1 β</i>	<i>Step 2 β</i>
30 day amount cannabis		-.244 *
<i>Global Guzzlers</i>		
IQ	-.052	-.090
Sex	-.038	-.052
ADHD Symptoms	.263 *	.254 *
Depression	.295	.321 *
Anxiety	.001	.012
30 day amount alcohol	-.049	.010
30 day amount nicotine	-.215	-.111
30 day amount cannabis		-.240 *

* significant at $p < .05$ level, uncorrected

** significant at $p < .01$ level, uncorrected