Chronic Marijuana Use, Inhibitory Control, and Processing Speed in Young Adult College Students

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ABSTRACT

Marijuana is the most widely used illicit substance in the United States, and its use is especially prevalent among young adults. Over the past two decades, there has been an overall decline in perceived harmfulness of marijuana use in young adults ages 18-30, despite growing evidence that chronic marijuana use may be associated with cognitive impairment. There have been mixed results regarding the effects of chronic marijuana use on inhibitory control. Furthermore, previous literature has shown inconsistent results regarding processing speed in marijuana users. The current study examined inhibitory control and processing speed in chronic marijuana-using young adult college students and healthy controls ages 18-22. 33 healthy controls (mean age: 19.18 ± 1.13; 18 male) and 28 chronic marijuana users (mean age: 20.25 ± 1.17; 19 male) were included in the study. Chronic marijuana users had to have used marijuana ≥5 times/week over the past year to be eligible. Participants were instructed to remain abstinent from marijuana use for 12 hours prior to the study visit. The 30-day Timeline Followback (TLFB) was used to assess recent marijuana use and participants were asked to estimate age at first marijuana use and lifetime days of marijuana use. Participants completed the Stroop Color Word Task (SCWT), and the interference t-score was used as a measure of inhibitory control. Furthermore, we examined marijuana use characteristics (i.e. age at first use, lifetime marijuana use, and past 30-day marijuana use) in relation to performance on the SCWT. Additionally, exploratory analyses investigated differences in the color and word conditions of the SCWT between the two groups and as a function of marijuana use characteristics. Results indicated no significant group differences on the interference, word, and color conditions of the SCWT. Furthermore, there were no significant correlations between age at first use, lifetime marijuana use, and past 30-day marijuana use with any conditions of the SCWT, but, there was a trend for greater past 30-day marijuana use to be associated with poorer performance on the color condition ($r(26) = -0.26$, $p = 0.09$). These findings indicate that chronic, heavy marijuana use may not be associated with impairments in inhibitory control or processing speed, which is consistent with other studies examining current use, heavy use, and chronic use in adolescents, young adults, and adults. Further research is needed to determine whether chronic, heavy marijuana use during young adulthood affects higher-order cognitive functioning skills needed for success in college, starting a career, and transitioning into adulthood.

Key words: marijuana, inhibitory control, young adults, executive function, processing speed

Marijuana (MJ) is the most widely used illicit substance in the United States, and its use is especially prevalent among young adults; 6% of 18-20 year-olds, and 9% of 21-22 year-olds reported daily MJ use in 2017 (NIDA, 2018; Schulenberg et al., 2018). The highest prevalence

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rates of annual and 30-day MJ use were among 18-22 year-olds (Schulenberg et al., 2018), which is concerning as this age group is still undergoing critical changes in biopscyhosocial maturation (Baggio et al., 2017; Sowell et al., 1999). Over the past two decades, there has been an overall decline in perceived harmfulness of MJ use in adults ages 18-30 (Schulenberg et al., 2018), despite growing evidence that chronic MJ use may be associated with cognitive impairment (Becker et al., 2014; Broyd et al., 2016; Crean et al., 2011; Yusoff et al., 2013). Heavy MJ use may negatively impact protracted brain maturation during young adulthood, possibly hindering the ability of youth to hone important cognitive skills needed for success in college, starting a career, and transitioning into adulthood. Thus, it is critical to determine whether heavy MJ use during young adulthood affects higher-order cognitive functioning skills that are still undergoing maturation (Fuster, 2002).

Inhibitory control is one domain of executive functioning defined as the ability to inhibit impulsive, habitual responses, subsequently allowing the selection of a more appropriate response; it allows for the possibility of change and choice (Diamond, 2013). One definition of inhibitory control is self-control, which involves the regulation of one's own behavior and emotions. Self-control allows for the resistance of temptations, discipline to stay on task, and delayed gratification (Diamond, 2013). However, another aspect of inhibitory control is interference control, which requires selective attention and allows the suppression of all stimuli except the target stimulus. Impaired inhibitory control has been associated with drug abuse and implicated in the maintenance of drug dependence (Crews & Boettiger, 2009; Goldstein & Volkow, 2002; Lubman, Yücel, & Pantelis, 2004). On the Stroop task, a measure of interference control, poorer performance on Stroop interference has been found in college student binge drinkers, methamphetamine-dependent individuals, cocaine polysubstance users, and other illicit drug users relative to healthy controls (Hallgren & McCrady, 2013; Salo et al., 2002; Verdejo-García & Pérez-García, 2007; Lillis et al., 2012); the current study aims to identify if heavy MJ use during young adulthood is associated with similar deficits in interference control. Examining inhibitory control in young adult heavy MJ users may help determine if chronic MJ use increases MJ users' risk of maladaptive behavioral outcomes.

While MJ use has been associated with impairments in many cognitive domains, including learning, memory, and attention, the findings regarding executive functioning, including inhibitory control, are mixed (Crean et al., 2011; Becker et al. 2014; Broyd et al., 2016; Yusoff et al., 2013). Research has consistently shown that acute MJ use is associated with impaired inhibitory control, but there have been mixed results regarding the effects of chronic MJ use on inhibitory control. Specifically, acute MJ intoxication has been associated with significantly increased stop reaction time and the proportions of commission and omission errors in the Stop signal task, a common measure of inhibitory control (Ramaekers et. al, 2006; Ramaekers et al., 2009; Metrik et al, 2012; Theunissen, et al., 2015). In addition, a number of studies have found that chronic MJ users show increased errors of commission and omission, and significantly poorer performance on the interference condition of the Stroop task (Gruber et al., 2012a; Sagar et al., 2015; Battisti et al., 2010; Dahlgren et al., 2016). However, there have been multiple studies indicating no difference in performance on inhibitory control measures between MJ users and non-users (Gruber & Yurgelun-Todd, 2005; Murphy et al., 2011; Price et al., 2015; Takagi et al., 2014; Takagi et al., 2011; Whitehurst et al., 2015). It is possible that smaller sample sizes for MJ users, such as the ones found in the latter studies (e.g. N= 10, 13, 27, 19, 19, and 17) may have contributed to the lack of group differences due to inadequate power to detect significant effects. Mixed findings on the effects of chronic MJ use on inhibitory control may also be related to length of abstinence prior to study participation, which is variable or unspecified in previous studies. A recent meta-analysis (Scott et al., 2018) found that studies requiring an abstinence period of 72 hours or more had effect sizes near zero, which may suggest that neurocognitive deficits are more likely to be present in individuals who are actively using MJ relative to those who have entered a period of abstinence. In addition, variables such as age at initiation of MJ use and frequency of MJ use have been found to predict poorer inhibitory control (Sagar et al., 2015; Dahlgren et al., 2016; Gruber

et. al, 2012b). Therefore, including these measures could better explain the impact of MJ use on inhibitory control. In addition to mixed results in the current literature, it remains unclear whether deficits in inhibitory control predate, or are a result of chronic MJ use. Poorer inhibitory control prior to the initiation of substance use has been found to predict increased substance use, including MJ, and dependence symptoms (Mahmood et al., 2013; Norman et al., 2011; Squeglia, Jacobus, Nguyen-Louie, & Tapert, 2014; Wetherill, Squeglia, Yang, & Tapert, 2013). Thus, it is difficult to determine whether premorbid impaired inhibitory control increases risk for chronic MJ use, or chronic MJ use relates to impairments in inhibitory control. Therefore, cross-sectional studies should also examine MJ use characteristics in relation to inhibitory control to help address this question.

Objectives

The current study aims to identify the effects of chronic MJ use on inhibitory control in young adult college students. We recruited chronic MJ using college students 18-22 years of age, who completed measures of substance use history and the Stroop task as part of a larger neurocognitive battery. In line with previous studies (Becker et al., 2014; Gruber et al., 2012; Solowij et al., 2011), participants were required to abstain from using MJ for 12 hours prior to the study visit to avoid the effects of acute intoxication on neurocognitive measures at the time of the study visit. This study recruited young adults within a narrow age range in order to determine how MJ use may affect inhibitory control during the protracted maturation of executive functioning; to our knowledge, the current study is one of few studies that have examined chronic MJ use on inhibitory control during young adulthood (Crane, Schuster, & Gonzalez, 2013; Lisdahl & Price, 2012). Participants completed the Stroop color-word task (SCWT), which is considered to be one of the most robust measures of inhibitory control (MacLeod, 1991). In the current study, we adopted the scoring method proposed by Golden (1978) to obtain an interference t-score for each participant. Thus, our study specifically measures interference control, a component of inhibitory control that involves selective attention, cognitive inhibition, and suppression of prepotent responses (Diamond, 2013). To understand how MJ use characteristics impact inhibitory control, the study also examined the relationship between lifetime days of MJ use, past 30-day occasions of MJ use, and age at first MJ use with Stroop performance. Previous studies found MJ use to be associated with reduced information processing speed (Fried, Watkinson, & Gray, 2005; Kelleher, Stough, Sergejew, & Rolfe, 2004; Lisdahl & Price, 2012); one of these studies found slower processing speeds on the Processing Speed Index in young adult current heavy MJ users (Fried, Watkinson, & Gray, 2005). The current study also explored differences in processing speed during the SCWT between the MJ users and healthy controls to identify potential deficits in processing speed in young adult chronic MJ users.

Hypotheses

The current study had three main hypotheses; first, we hypothesized that chronic MJ users will exhibit impaired interference control on the Stroop task compared to healthy controls; second, we predicted that lifetime days of MJ use and frequency of past month MJ use in MJ users would be negatively correlated with interference control; third, we predicted age at first MJ use in MJ users would be negatively correlated with interference control in MJ users (i.e. using MJ at an earlier age predicts more severe impairment in inhibitory control).

METHOD

Participants

Participants were recruited through flyers, word of mouth, snowball sampling, and social media advertising. Participants who contacted the laboratory reviewed the consent form with study staff and informed consent was obtained from participants who were interested in completing the eligibility interview. Eligible participants were 18-22 year old college or university students who met inclusionary criteria for the healthy control (HC) (N=33) or chronic MJ user (N=28) group. Exclusionary criteria for all participants included: <18 or >22 years of age; inadequate knowledge of the English language (e.g. not fluent); pregnancy; uncorrected visual impairments; self-reported lifetime history of a

diagnosed psychiatric disorder; learning disability; self-reported current use of psychotropic medications; major neurological/medical illness; significant head trauma; prenatal exposure to drugs or alcohol; premature birth (<35 weeks gestation); and reported history of psychotic disorders in immediate biological relatives (e.g. schizophrenia or bipolar I). Because exclusionary criteria included a lifetime history of a diagnosed psychiatric disorder, participants with Attention Deficit Hyperactivity Disorder (ADHD) have been excluded from the study; thus, some participants with impairments in inhibitory control may have been excluded from the sample since deficits in inhibitory control have been identified as a core component of ADHD (Jacobson, Schneider, & Mahone, 2017). These criteria were set in place to exclude participants who may have atypical performance on measures of executive functioning not associated with MJ use.

HCs were excluded for significant substance use history (>51 lifetime drinks [Pfefferbaum et al., 2016], lifetime history of >5 drinks/occasion for males/>4 drinks/occasion for females, >90 lifetime cigarettes, MJ use more than once/month in the past year, and any other illicit drug use). MJ users reporting >15 lifetimes occasions of past use of other illicit drugs or recreational use of over-the-counter medications were also excluded to limit the effects of polysubstance use on executive functioning. Inclusionary criteria for participants in the MJ group were at least 5 occasions of MJ use/week in the past year. Alcohol use was not exclusionary for the MJ group given the prevalence of alcohol and MJ co-use among young adults (Norton & Colliver, 1988; O'Hara, Armeli, & Tennen, 2016). Since problem drinking and recent binge drinking have been associated with impaired inhibitory control (Gan et al., 2014; Hallgren & McCrady, 2013; Hu, Zhang, Chao, Krystal, & Li, 2016; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009), appropriate statistical measures were performed to control for alcohol use in the current sample. All procedures were approved by Oregon State University's Institutional Review Board (IRB) and followed the ethical guidelines of the IRB. Data on other tasks of executive functioning from this participant sample has been previously published in another manuscript (Lahanas & Cservenka, 2019).

Procedures

Eligible participants were invited into the lab for a study visit in which they completed measures of substance use, psychosocial functioning, and neuropsychological tasks to assess executive functioning, including the Stroop task. Following consent, participants provided a urine sample for a 12-panel urine toxicology test (CLIA Waived, Inc.), which was used to identify recent substance use and a breathalyzer (BACtrack Breathalyzer) to ascertain absence of alcohol intoxication. Participants were asked to abstain from MJ use for at least 12 hours prior to the study visit to limit the effects of acute intoxication on neurocognitive measures. Furthermore, a longer abstinence period was not required as this study was interested in examining how ongoing heavy MJ use affects inhibitory control, as opposed to examining how neurocognitive performance is affected by abstinence from MJ use, and withdrawal symptoms, which typically begin 24-48 hours after abstinence (Greydanus, Hawver, Greydanus, & Merrick, 2013; Haney et al., 2004). As MJ users may have reported some illicit substance use, they were not excluded from analyses due to positive urine toxicology for any substance. One HC tested positive for tetrahydrocannabinol at the time of the study visit, but as HCs may have used MJ within the past month (MJ use ≤ once/month in the past year), they were not excluded from analyses. One HC participant tested positive for opiates at the time of the study visit but did not report opiate use during the eligibility interview.

Measures

Participants completed a brief demographic questionnaire and measures of substance use. Recency, and frequency of MJ, alcohol, nicotine, and other substance use was assessed with the Timeline Followback (Robinson et al., 2014; Sobell & Sobell, 1992), which asked participants to indicate their substance use in the 30 days prior to the study visit, including the day of the study visit. Participants were also asked to estimate the total number of days they used MJ in their lifetime and their age at first MJ use.

General intelligence was assessed by the 2-subtest version of the Wechsler Abbreviated Scale of Intelligence-II (WASI-II) (Wechsler, 2011),

while inhibitory control was examined with the Stroop Color-Word Test (SCWT) (Golden, 1978). For the SCWT, participants read three different tables as quickly and as accurately as they could for 45 seconds each. Two of the tables represent a "congruent condition", for which participants read names of colors printed in black ink (Word condition, or W) and named different color patches (Color condition, or C). The "incongruent condition" uses a table of color-words (Color-Word condition, or CW) printed in inconsistent color ink (e.g the word "green" is printed in red ink); the participants were required to read the name of the color of the ink instead of reading the word. The CW condition challenges participants to inhibit the interference coming from a more automated task (i.e. reading the word). The current study uses the scoring method proposed by Golden (1978). In this method, the number of items correctly named in 45 seconds in each condition (i.e. W, C, CW) is calculated and used to determine the predicted Color-Word score (Pcw). Then, the Pcw value is subtracted from the actual number of items correctly named in the CW condition to obtain an interference t-score (IG) (i.e. IG = CW-Pcw); a lower score represents greater difficulty in interference control, while a negative IG value represents severe impairment in interference control (Scarpina & Tagini, 2017).

Statistical Analysis

For all statistical analyses, SPSS Version 25.0 (IBM Corp., 2017) was used. Demographic variables and dependent variables from the SCWT were examined for skewness and kurtosis values to determine whether parametric or non-parametric tests (skewness or kurtosis >2) were appropriate for analyses. Furthermore, Levene's test was used to assess equality of variances for the MJ and HC groups. Demographic and substance use variables were compared between groups using chi-square, independent samples t-tests, or Mann-Whitney U-tests as appropriate. Demographic and substance use variables significantly different between the groups were examined in relation to SCWT performance, and those variables significantly related to SCWT performance were included as covariates in analyses. To determine group differences in interference control on the SCWT, an independent samples t-test was used to compare groups on IG. Pearson or Spearman correlations were performed to examine the relationship between days of lifetime MJ use, past 30-day MJ use occasions, and age at first MJ use with performance on the SCWT. To examine the effects of MJ use on processing speed, t-scores for the word and color conditions of the SCWT were used to conduct exploratory data analyses. Groups were compared on color and word t-scores using independent samples t-tests and the effects of substance use variables on word and color t-scores were examined using Pearson or Spearman correlations. A significance level of $p < 0.05$ was set for all statistical tests.

RESULTS

The HC and MJ groups were well matched on all demographic variables except for age and IQ (see Table 1), as MJ users were significantly older than HC and had a significantly lower mean IQ score relative to HC. However, age and IQ were not significantly associated with interference t-scores, color t-scores, or word t-scores (all p's > 0.10) and thus were not included as covariates in our analyses. As expected, groups differed on a number of substance use measures (see Table 1) as a result of eligibility criteria for participation in the study. Given that the majority of HC had never used MJ (N = 27), MJ use characteristics were examined in relation to the dependent variables only within the MJ group. None of the alcohol or cigarette use measures were correlated with the dependent variables (all p's > 0.10). Thus, they were not included as covariates in our analyses.

There were no significant differences between the MJ and HC groups on the interference t-score ($t(59) = 1.0$, $p = .17$), color t-score ($t(59) = .811$, $p = .42$), or word t-score ($t(59) = 1.62$, $p = .11$). Within the MJ group, there were no significant correlations between log transformed lifetime MJ use ($r(26) = -0.25$, $p = 0.11$), square root transformed past 30-day MJ use ($r(26) = -0.005$, $p = .49$), or age at first MJ use ($r(26) = 0.22$, $p = .13$) and interference t-scores. There were no significant correlations between log transformed lifetime MJ use ($r(26) = -0.05$, $p = .39$), or age at first MJ use ($r(26) = -0.06$, $p = 0.38$) and color t-scores, but there was a trend towards a significant relationship between square root transformed

Table 1. *Demographic Characteristics and Substance Use Measures*

Demographics	Controls (N=33)	MJ Users (N=28)	*t* or χ^2	*p*
	M(SD)	M(SD)		
Age	19.19(1.13)	20.25(1.17)	-3.61	.001
Sex (M/F)	18/15	19/9	1.13	.290
Hispanic/Latino (N)	3	3	0.05	.832
Race (N)			1.8	.614
White	22	22		
Asian	4	1		
More than one race	6	4		
Unknown	1	1		
SES			1.66	.789
Poor	1	1		
Lower middle class	1	1		
Middle class	20	14		
Upper middle class	11	11		
Wealthy	0	1		
WASI-II Full-Scale IQ	118.42(13.63)	107.14(12.6)	3.34	.001
Substance Use Measures	Controls (N=33)	MJ Users (N=28)	*U*	*p*
Age at first MJ use	17.57(1.5)	16.39(1.55)	47	.090
Lifetime MJ use days	23.06(126.94)	1041.89(609.53)	9.5	< .001
Past 30-day MJ use	0.06(.24)	48.54(31.79)	0	< .001
Age at first drink	17.38(1.47)	16.71(1.72)	274.5	.250
Lifetime drinks	15.67(17.07)	409.14(629.24)	67.5	.001
Past 30-day drinks	1.98(3.66)	19(17.93)	119	< .001
Age at first cigarette	18(1)	17.94(1.47)	8.5	.930
Lifetime cigarettes	.03(.17)	41.75(135.19)	170	< .001
Past 30-day cigarettes	.03(.17)	17.68(3.34)	391	.050
Lifetime Illicit Substance Use	0	3.21(3.36)	148.5	< .001

past 30-day MJ use and color t scores (Figure 1; $r(26) = -0.26$, $p = 0.09$). - There were no significant correlations between log transformed lifetime MJ use ($r(26) = -0.02$, $p = 0.46$), square root transformed past 30-day MJ use ($r(26) = -0.03$, $p = 0.43$), or age at first MJ use ($r(26) = -0.01$, $p = 0.47$) and word t-scores.

DISCUSSION

The current study investigated whether chronic MJ use is associated with impairments in inhibitory control in young adult college students. There were no significant group differences on inhibitory control between healthy controls and chronic MJ users, nor were there significant correlations between MJ use measures (i.e. lifetime MJ use, past 30-day MJ use, and age at first MJ use) and dependent variables (i.e. interference t-scores, color t-scores, and word t-scores). However, there was a trend such that MJ users who reported greater past 30-day MJ use tended to name fewer colors during the color condition of the SCWT, suggesting that greater recent MJ use may be associated with slower processing speeds.

While previous studies have reported mixed findings when examining the association between

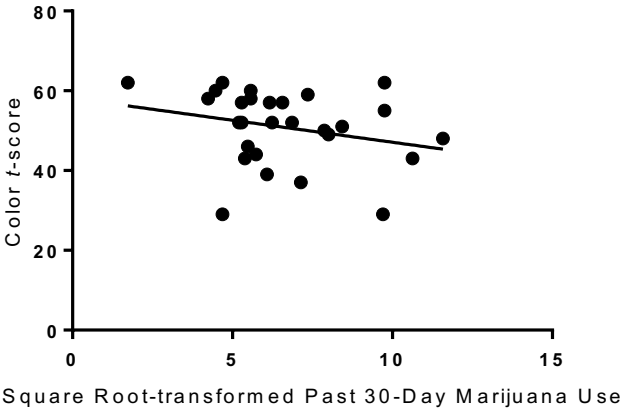

Figure 1. *Trend between more past 30-day MJ use and smaller color t-scores suggesting longer response times and slower processing speeds on the color condition of the SCWT.*

chronic MJ use and impairments in inhibitory control, our study has found results similar to others (Cousijn et al., 2013; Gonzalez et al., 2012; Griffith-Lendering, Huijbregts, Vollebergh, & Swaab, 2012; Gruber, et al., 2012a; Gruber et al., 2012b; Price et al., 2015; Takagi et al., 2011; Whitehurst, Fogler, Hall, Hartmann, & Dyche, 2015). Gruber et al. (2012a; 2012b) found that chronic MJ users and healthy controls performed similarly on the interference condition of the Multisource Interference Task and the SCWT. Additionally, Takagi et al. (2011) did not find any differences in inhibitory control on the SCWT or Go/No-Go task between healthy controls and cannabis users. Another study found no group differences on the Delis-Kaplan Executive Function System color-word interference in a sample of emerging adults (Price et al., 2015). These studies had sample sizes similar to our user group of 28 (i.e. 34 users, 23 users, 19 users, and 27 users). Similar to our lack of significant findings between MJ use frequency and the SCWT, another study found no associations between MJ consumption and accuracy on the SCWT (Thayer et al., 2015). Further, our results support previous work that has not found cannabis use to be associated with slower processing speed (Becker et al., 2014; Hanson et al., 2010; Nguyen-Louie et al., 2015). For example, Becker et al. (2014) did not find slower processing speeds in 18-20 year-old chronic MJ users on the Digit Symbol.

There are several potential explanations for the absence of significant findings regarding inhibitory control in the current study. Limited statistical power due to our small sample size (28 chronic MJ users and 33 healthy controls) may have played a role in our inability to detect any significant associations. Post-hoc power analysis for group differences on the interference t-score [G*Power (Faul, Erdfelder, Lang, & Buchner, 2007)] revealed that we obtained statistical power of 0.26 given the sample size (N = 61) and effect size of 0.26. Interestingly, even though the current study did not find significant group differences on inhibitory control between MJ users and HCs, a recent meta-analysis found that published studies examining the effect of MJ use on inhibitory control had similar effect sizes to ours (d = 0.25; Scott et al., 2018).

Also, given that recent research has shown that initiating regular cannabis use at an earlier age is related to poorer neurocognitive performance (Dahlgren et al., 2016; Ehrenreich et al., 1999; Gruber et al., 2012; Lisdahl, Gilbart, Wright, & Shollenbarger, 2013; Pope et al., 2003; Sagar et al., 2015), considering age of onset may have yielded more insight into the relationship between MJ use and inhibitory control; we did not find any significant associations between age at first use and inhibitory control, possibly because using a substance for the first time does not accurately reflect regular use and associated consequences. Furthermore, many previous studies finding no group differences on measures of inhibitory control between MJ users and controls also examined this relationship in young adults (Gonzalez et al., 2012; Griffith-Lendering et al., 2012; Price et al., 2015; Whitehurst et al., 2015). Alternatively, many previous studies that reported inhibitory control impairments in MJ users compared to controls had examined either adolescents or adults (Battisti et al., 2010; Behan et al., 2014; Dahlgren et al., 2016; Dougherty et al., 2013; Fontes et al., 2011; Sagar et al., 2015). Thus, it is possible that the current study was unable to observe impairments due to our restricted age range, or due to the age range itself. Possibly, impairments are most evident with active heavy MJ use in adolescence, when cognitive maturation may be more vulnerable to potential neurotoxic effects of MJ use, or in adulthood after a longer exposure to MJ use has occurred.

The current study has a few limitations of note. While we required abstinence from MJ users 12 hours prior to the study visit, we cannot ascertain whether participants adhered to this requirement, though no participants appeared intoxicated at the time of the study visit. Furthermore, our sample was limited to college students, thus our findings may not be generalizable to non-college young adults, who have three times the rate of daily MJ use relative to college students (non-college: 13.2%; Schulenberg et al., 2018). Finally, because our sample specifically examined chronic MJ use (i.e. using 5+ times/week over the past year), our findings may not reflect cognitive performance in infrequent young adult MJ users.

In the current study, chronic MJ users did not show any significant impairments in inhibitory control or processing speed compared to healthy controls, and MJ use characteristics were not associated with impairments in inhibitory control or processing speed. Because the findings of the current literature remain mixed, the current findings could help inform future researchers' decisions to further investigate these relationships. Further investigation is warranted to determine whether there exists a relationship between chronic MJ use and impaired inhibitory control. If such a relationship exists, chronic MJ users may be at risk of developing a substance use disorder due to their difficulty in inhibiting impulsive, habitual drug use behaviors. In this way, intervention efforts could emphasize techniques aimed at reducing impulsive behaviors. Longitudinal studies measuring inhibitory control before MJ use initiation, during a period of chronic MJ use, and after a period of MJ abstinence would be invaluable in determining the effects of MJ on inhibitory control and if potential impairments are reversible with abstinence.

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