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Relationship Between Cannabis Use and Immediate, Delayed, and Working Memory Performance Among Older Adults

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RELATIONSHIP BETWEEN CANNABIS USE AND IMMEDIATE, DELAYED, AND WORKING MEMORY PERFORMANCE AMONG OLDER ADULTS

by

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ABSTRACT

Cannabis is increasingly accessible in the United States for recreational and/or medical use. Additionally, the Baby Boomer birth cohort exhibits a greater prevalence of cannabis use than prior generations of older adults. Past research has most frequently addressed the potential cognitive effects of cannabis use in populations of adolescents and young adults. Some of these studies suggest that cannabis use is chronically associated with worse performance on tasks of verbal working memory and executive functioning, however, due to methodological variation and a wide variety of potential confounds including duration of abstinence and frequency of use, results are still inconclusive. Through use of a longitudinal, publicly available secondary dataset, the Health and Retirement Study, immediate, delayed, and working memory were evaluated in older adults who have used cannabis within the past year, within their lifetime but not the past year, and those who have never used. Uncontrolled, one-way ANOVAs and controlled ANCOVAs were used to examine these effects. When controlling for age, gender, education, and race, current frequent users demonstrated significantly worse immediate memory performance than past and non-users. Results suggest that greater than weekly cannabis use may result in attentional and short-term memory deficits. Further, these effects may be mitigated by sustained abstinence over time. Certain limitations including sample size and measures of cannabis use warrant future studies to replicate and build upon these findings.

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

The cannabis plant has been used for centuries, yet still incites controversy today. In recent years, the prevalence of cannabis use has increased among older adults partially due to cohort effects. Specifically, the adult population groups aged 50-64 and 65+ underwent a significant increase in use from 2006/07 to 2012/13 as the baby boomer generation began to age into these groups (Han et al., 2017). The cognitive and physiological effects of cannabis use in adolescents and young adults have been well-documented to date. However, the current compilation of research regarding the effects of cannabis use on older adults leaves much to be desired. Older adults (individuals aged 65 and above) are a vulnerable population facing challenges including age-related cognitive decline and other health concerns. As current legislature shifts towards the authorization of cannabis use for medicinal purposes, cannabis use overall shows an upward trend, especially in those born after 1945 as compared to older generations, and this can be attributed to both birth cohort and period effects (Kerr et al., 2018). Taking these factors into consideration, in combination with the increased likelihood of older adults to have medical conditions which qualify for treatment with medicinal cannabis (also known as medical marijuana), studying the cognitive effects of cannabis usage in older adults is a matter of both public health and scientific interest.

Cannabis is used for both medical and recreational purposes. Plants of the Cannabis genus, sometimes collectively referred to as ‘marijuana’, are made up of hundreds of cannabinoids – two of the most prevalent being delta-9-tetrahydrocannabidiol (THC), the psychoactive component that provides users with a “high,” and cannabidiol (CBD), a non-psychoactive constituent (Rosenberg et al., 2015) which is often thought to oppose and mitigate

some of the effects of THC on the brain (Bhattacharyya et al., 2010). Investigations of the medicinal benefits of cannabinoids are ongoing. In 2017, the National Academy of Sciences released a report on the Health Effects of Cannabis and Cannabinoids, synthesizing the currently understood health benefits and drawbacks of cannabis use. They reported substantial evidence that cannabis has efficacy in treating cancer-related nausea, chronic pain in adults, and patient-reported spasticity due to multiple sclerosis (MS), along with moderate evidence supporting improvement of sleep outcomes in certain sleep disturbance conditions, and limited evidence for increasing appetite in HIV/AIDS patients and improvement of Tourette syndrome symptoms (National Academies of Sciences Engineering and Medicine, 2017). Alongside these potential therapeutic effects, cannabis is known to cause concomitant physiological symptoms and adverse events, including disorientation, dizziness, and gastrointestinal problems (Whiting et al., 2015), an increased risk of psychosis (Moore et al., 2007), and, most relevant for the purpose of this research, alterations to cognition and neuropsychological performance (Broyd et al., 2016; Gonzalez et al., 2017; Lyons et al., 2004; Nader & Sanchez, 2018), as well as changes in brain structure (Lorenzetti et al., 2019). The National Academy of Sciences reports moderate evidence of a statistical association between acute cannabis use and impairments in memory, learning, and attention, but limited evidence of an association between sustained abstinence from cannabis and impairments in these three domains (National Academies of Sciences Engineering and Medicine, 2017).

Memory is the most commonly identified cognitive domain affected among cannabis users (Broyd et al., 2016). More specifically, verbal learning and memory (assessed via recall and recognition tasks) are likely impacted by both acute and chronic use of cannabis (Broyd et

al., 2016). However, both the extent and duration of long-term effects are less clear across studies, potentially due to discrepancies in consideration of factors such as duration of abstinence prior to cognitive testing and cumulative exposure to cannabis. With a minimum of 12 hours since last cannabis use, for example, verbal learning, recall, and retention are significantly worse in adolescent users as compared to controls (Solowij et al., 2011). Additionally, in this study, verbal learning and recall performances were increasingly worse in adolescents with a younger age of onset and greater amount, frequency, and duration of cannabis use. Notably, regarding age of onset, the National Academy of Sciences has concluded initiation of marijuana use prior to age 25 may affect developmental outcomes, although presently, research is limited and inconclusive (National Academies of Sciences Engineering and Medicine, 2017). A longitudinal cohort study of young adults over a period of 25 years found that higher cumulative consumption of cannabis was associated with increasingly worse verbal recall in middle aged adults, although duration of abstinence was not addressed prior to testing (Auer et al., 2016). Another study found recent use of cannabis (28 days or less since last use) to be associated with significantly worse performance on tasks of working memory, attention, processing speed, and executive function, as compared to non-users (Thames et al., 2014). However, the latter two studies do not account for the duration of time that has passed since participants' last cannabis use, which leaves open the potential that cognitive impairments may be attributed to residual effects of cannabis lingering in the central nervous system.

Literature addressing the impact of cannabis use on executive functioning is widely divergent in methodology and conclusions and is thus inconclusive. Both memory and executive functioning are found to be impaired in abstinent cannabis users as compared to controls in some

studies, but not others (Ganzer et al., 2016). Researchers identify mixed evidence for whether executive functions are chronically impaired in cannabis users, suggesting that factors such as age of onset, frequency of use, duration of abstinence prior to cognitive testing, and lifetime cumulative exposure to cannabis may affect presentation of executive functioning detriments (Broyd et al., 2016; Ganzer et al., 2016). Interestingly, impairments in executive function are more consistently identified in samples of middle-aged populations as compared to younger samples, which may reflect the aftermath of a disruption in development due to early age of onset, or simply greater cumulative exposure (Broyd et al., 2016). The same 25-year longitudinal study which found that verbal memory deficits were associated with cumulative exposure also found an association of ongoing use of cannabis with poorer executive function and processing speed but was unable to identify such differences in past-users compared to non-users (Auer et al., 2016). In another systematic review taking the aforementioned potential confounds into consideration, with a mean age of 30 for both cannabis users and controls, researchers found that long-term cannabis users showed significantly worse learning and memory, executive functioning, and global cognitive functioning than controls, all of which persisted after 25 days of abstinence except for executive function deficits, which were no longer significant (Lovell et al., 2020). Overall, the effect of cannabis use on cognition is not entirely clear and calls for further investigation with various confounds and limitations taken into consideration.

Between studies, results remain inconsistent over the cognitive effects of cannabis in adult and adolescent cannabis users who are abstinent for a minimum of 14 days as to account for any residual effects of the drug (Ganzer et al., 2016). Further, adolescents performed worse than controls on verbal learning and recall after only 3 days of abstinence, and still had worse

memory performance after 2 weeks of abstinence, but after 3 weeks without cannabis, adolescent users performed similarly to controls, suggesting that residual effects of cannabis may resolve after a few weeks (Hanson et al., 2010). Consistent with this, there have been numerous meta-analyses addressing the duration of residual verbal memory deficits which yield similar results. In an analysis of 33 studies, mild to moderate residual neurocognitive effects were identified in cannabis users; however, in studies with 25 or more days of abstinence, no residual effects were observed, suggesting that they had resolved after this period of abstinence (Schreiner & Dunn, 2012). However, researchers advocate for confound control, including withdrawal effects and methodological flaws, in future studies in order to confirm these results (Schreiner & Dunn, 2012). Another meta-analysis demonstrated verbal learning deficits with 7 days of abstinence or fewer, but no difference in performance otherwise, however, they acknowledge that other factors such as years of use might also play a role in this relationship (Krzyzanowski & Purdon, 2020). While there is some evidence that neurocognitive deficits resolve after a prolonged period of abstinence, very few studies have focused solely on older cannabis users, and thus, cognition in these populations still needs to be addressed.

In order to fully understand the impact of cannabis on the brain it is essential to consider the endocannabinoid system: an endogenous system involved in a wide range of functions including regulation of memory, learning, and reward processing (Maldonado et al., 2006; Morena & Campolongo, 2014), and modulation of pain, movement, and appetite (Ashton et al., 2017). The human body naturally produces endocannabinoids. These are lipophilic molecules that activate the type 1 and type 2 cannabinoid receptors, or CB1 and CB2, respectively, which are also activated by exogenous cannabinoids such as CBD and THC (Maccarrone et al., 2015).

THC produces its psychoactive effects by binding to the CB1 receptor (Glass et al., 1997). CB1 receptors are mostly found in the central nervous system, and are highly concentrated in a few regions including the hippocampus, prefrontal cortex, and basal ganglia (Ashton et al., 2017), while CB2 receptors are found primarily in the immune system (Ashton et al., 2017) and in some regions of the brain (Onaivi, 2006). Among heavy cannabis users, the greatest amount of structural abnormalities are located in brain regions with the highest concentrations of CB1 receptors: most notably including the hippocampus, followed by highly CB1-concentrated regions of the prefrontal cortex, the amygdala, and cerebellum (Lorenzetti et al., 2016). In a subsequent meta-analysis, researchers identified that regular cannabis users (aged 21-40, with an age of onset between age 15-20) had smaller volume of the hippocampus and orbitofrontal cortex (Lorenzetti et al., 2019). Again, similar analyses in older samples are limited. Before addressing how cannabis use affects cognition in older adults, it is necessary to address cognitive functioning patterns and detriments characteristic of non-using older adults.

Age-related cognitive decline is common, but research shows that it may be mitigated by: accumulation of neuronal resources (reserve) which can be attributed to factors such as greater educational duration and increased physical activity; preservation and repair of existing neuronal resources (maintenance); and recruitment of neuronal resources from unconventional brain networks for successful processing and task completion (compensation) (Cabeza et al., 2018). The compensation effect is demonstrated by the following finding: certain populations of older adults demonstrate levels of cognitive performance comparable to that of younger adults. These high-performing older participants show greater cortical recruitment compared to the younger participants and compared to worse-performing older adults (Riis et al., 2008). Normal cognitive

aging is associated with slow but steady cognitive decline in working and episodic memory and attention, along with corresponding structural changes in brain regions including the prefrontal cortex (Cabeza et al., 2018) and certain areas of the hippocampus (Malykhin et al., 2017). Some older individuals may receive a DSM-5 diagnosis of mild neurocognitive disorder, which is employed clinically to characterize non-impairing, yet measurable decline in cognitive performance (Blazer, 2013). More severe neurocognitive decline occurs with age-related diseases such as Alzheimer's Disease and related dementias (ADRD). A wide range of environmental and genetic factors have been associated with greater risk for ADRD such as, but not limited to: years of education, level of physical activity, cholesterol, hypertension, obesity, diabetes, and carriage of the ApoE-4 gene (Clouston et al., 2020; James & Bennett, 2019; Kuzma et al., 2018; Profenno et al., 2010; Raz et al., 2003).

Considering the variation in cognitive performance and influential factors in older adults, and that cannabis likely impairs cognition in younger adults, an exploration of cognition in older adult cannabis users is warranted. Current research is sparse in number and variant in focus. With regard to cognition and cortical changes, a recent pilot study of cannabis use in adults 60 years and older who had used cannabis weekly for the past year or longer (with an average of 23.5 years of use), exclusive of participants with uncontrolled hypertension or diabetes. Assessments accounted for working memory, episodic memory, vocabulary, attention, executive function, and processing speed; resultantly there were no differences in cognitive functioning between users and non-user controls, and few differences in cortical volume (Thayer et al., 2019). However, this study was notably limited by its cross-sectional nature and low external validity due to exclusion of certain health conditions, so it was suggested that future studies

investigate the interaction of age and cannabis use in a larger sample (Thayer et al., 2019). Another line of inquiry focuses on the endocannabinoid system in older adults, with respect to both normal cognitive aging and ADRD. Emerging neuroscientific research suggests that specific changes may occur in the endocannabinoid system in patients with ADRD including altered expression of CB1 and CB2 receptors, however, often times these studies are somewhat lacking in confound control so results are mixed and current study designs need improvement (Berry et al., 2020). In animals, administration of low-dose THC to older mice experiencing age-related cognitive decline *improved* cognition during treatment and for several weeks after cessation, as compared to vehicle-treated controls (Bilkei-Gorzo et al., 2017). Interestingly, a recent review paper integrated findings on the suggested small-dose protective effect of THC with the commonly identified cognitive impairments in heavy cannabis users, indicating that THC may in fact employ a biphasic effect in older individuals – a J-shaped phenomenon used to describe a substance which is beneficial at small doses and toxic in larger doses (Calabrese & Rubio-Casillas, 2018). Similarly, a final study which should be cautiously considered claims that marijuana-naïve older adults exhibited improvements in executive functioning (specifically, cognitive control) after 3 months of treatment with medicinal cannabis, although the sample size was small and no control group was used (Gruber et al., 2017).

THE CURRENT STUDY

Taken together, previous findings that cannabis impairs cognition in younger populations coupled with the inconclusive evidence of beneficial cannabinoid effects in older adults suggests a gap in the literature which needs to be addressed. Thus, the goals of this manuscript are to examine competing hypotheses regarding the relationship between cannabis use and immediate, delayed, and working memory in older adults. Some literature (Auer et al., 2016; Broyd et al., 2016; Ganzer et al., 2016; Lovell et al., 2020; Thames et al., 2014) suggests that cannabis use is associated with escalating degrees of impairment in verbal working memory and executive performance, suggesting a linear relationship between use and cognition. This relationship may be exaggerated by factors such as age of onset (Meier et al., 2012) and greater frequency of use (Broyd et al., 2016). A second body of literature (Bilkei-Gorzo et al., 2017; Calabrese & Rubio-Casillas, 2018; Gruber et al., 2017) suggests a competing hypothesis characterized by a hormesis effect: low to moderate levels of cannabis use may be associated with relative benefits to working memory and executive performance, whereas heavy use is associated with decrement of these cognitive domains. Therefore, hypotheses are as follows:

> Hypothesis: Cannabis non-users, past users, current occasional (less than weekly) users, and current frequent (at least weekly) users will differ in performance on working memory, immediate memory, and delayed memory.

METHODOLOGY

Participants

Participants in this study were drawn from the longitudinal Health and Retirement Study (HRS) conducted by the University of Michigan and supported by the National Institute on Aging (grant number NIA U01AG009740). The HRS includes adult respondents of age 50 years and older living in the United States and assesses factors related to health, retirement, and aging via telephone and in-person interviews. Data collection in the HRS is bi-annual, beginning in 1992 and continuing today (Health and Retirement Study, 2018). In this study, data from the 2018 wave of participants was used. Specifically, respondents to the question "*Have you ever used marijuana or hashish?*", found in the Module 4 Questionnaire, were included for data analysis.

Measures

Demographic data was obtained from the HRS Cross-Wave Tracker File. This data accounted for respondent age, masked race (White/Caucasian, Black/African American, Other), which was dichotomized into White and Non-White for the purpose of this study, ethnicity (Not Hispanic, Hispanic), gender (male, female), and years of cumulative education.

Cannabis use was defined by respondent answers to the Module 4 Questionnaire. Prior to grouping, participants under the age of 50 (born in or after 1969) were filtered out of the dataset. Respondents were then divided into groups as follows, based on recency and frequency of cannabis use. A control group of *non-users* (n = 886) indicated that they have never "used marijuana or hashish", while *users* (n = 462) indicated that they have. Users who subsequently

responded “NO” to the question, “Have you used marijuana or hashish within the past year?” were considered *past users* (n = 334), while those who responded “YES” were *current users* (n = 148). Current users were then divided into one of two categories, based on the question “When you used marijuana or hashish most frequently, about how often did you use it?”. *Current occasional users* (n = 36) indicated that at the time of their heaviest marijuana use, they used less than 52 times per year. *Current frequent users* (n = 92) indicated use 52 times per year or more.

Cognition data was obtained from the 2018 HRS Core file – specifically, Section D: Cognition (Respondent). Working memory was assessed using the Serial 7’s task, whereby participants must count backwards in increments of 7 and are given one point for each correct answer out of 5 answers in total (Folstein et al., 2001).

Immediate free-recall and delayed (five minute) free-recall (Ofstedal et al., 2005) were assessed using a 10-item wordlist task. Final score reflected the number of correct responses.

Procedures

Descriptive analyses were conducted to evaluate differences in demographics and key variables of interest between cannabis use groups. This process aided in characterization of the sample and identification of critical control variables based on statistically significant differences between groups based on aforementioned descriptive variables: gender, age, masked race, ethnicity, and years of education (which may account for variability in cognitive performance).

Primary hypotheses were tested using uncontrolled, one-way analyses of variance (ANOVA) and analysis of covariance (ANCOVA) including age, gender, education, and race.

Materials

Publicly available Health and Retirement Study (HRS) data were accessed using IBM SPSS software, Version 27. Public data files used included the HRS Cross-Wave Tracker file and the 2018 HRS Core file (Section D). Access to the Module 4 Questionnaire, which is considered Sensitive Health Data, required additional documentation. IRB approval was obtained for commencement of this project (STUDY00002680), which was not determined to be human subjects research. No other materials were required for this study.

RESULTS

The sample included 1348 participants (59% female; n = 805). Demographic data is provided in Table 1. The sample was predominantly White (67%). Participant age ranged from 50-98 years old, with an average age of 67.59 years (*SD* = 10.76). Participants had 13.04 years of education on average (*SD* = 3.08). Participants were categorized as cannabis non-users (n=886), past users (n=308), current occasional users (used less than 52 times per year; n=36), or current frequent users (used 52 times or more per year; n=92). Within the current occasional use group, 50% of respondents used cannabis 1-3 times per year (n=18), 27.8% used 6-12 times per year (n=10), and 22.2% used 2-4 times per month (n=8). Within the current frequent use group, 42.4% of respondents used 1-3 times per week (n=39), 35.9% used 4-7 times per week (n=33), and 21.7% used 2 or more times per day (n=20).

Table 1

Sample Characteristics (N=1348)

Variable	Mean (SD) or %
Age	67.59 (10.76)
Gender (female)	59.00%
Race (masked)	
White/Caucasian	67.00%
Black/African American	21.70%
Other	11.00%
Hispanic ethnicity	14.30%
Education level (years)	13.04 (3.08)
Immediate recall	5.53 (1.63)
Delayed recall	4.57 (1.97)
Serial 7s	3.48 (1.69)
Cannabis use	
Current occasional	2.70%
Current frequent	6.80%
Past user	24.80%
Non-user	65.70%

Assumptions of ANOVA-based statistical procedures, as were used in this study, are that data are essentially normally distributed, that error is normally distributed, and that the groups are similar with respect to variance. Additionally, these tests assume an adequately powered sample. For this sample, immediate and delayed memory scores were essentially normal upon visual inspection. Scores on the serial 7's task were negatively skewed, and a perfect score of 5 was the modal score. Given the shape of the distribution, data transformations would not likely have improved compliance with parametric assumptions. Where possible, non-parametric analyses were employed. Because groups were variable in size, the Sidak post-hoc comparison procedure was employed.

Uncontrolled, one-way ANOVAs and controlled ANCOVAs were used to examine the effects of cannabis use on immediate memory, delayed memory, and working memory. Uncontrolled analyses found that cannabis use group was associated with immediate memory, $F(3,1246)=6.14$, $p<.001$, $\eta_p^2=.015$. When controlling for gender, $F(1,1232)=11.52$, $p=.001$, $\eta_p^2=.009$; education, $F(1,1232)=90.11$, $p<.001$, $\eta_p^2=.068$; age, $F(1,1232)=111.92$, $p<.001$, $\eta_p^2=.083$; and race, $F(1,1232)=16.46$, $p<.001$, $\eta_p^2=.013$, cannabis use was associated with immediate memory, $F(3,1232)=3.75$, $p=.01$, $\eta_p^2=.009$. Specifically, post-hoc findings were that current frequent users' ($M=4.94$, $SE=.16$) immediate memory was worse than that of both non-users ($M=5.48$, $SE=.06$) and past users ($M=5.49$, $SE=.09$; $p<.05$ for both).

Uncontrolled analyses suggested a significant main effect of cannabis use on delayed memory $F(3,1245)=3.75$, $p=.01$, $\eta_p^2=.009$. Post hoc findings revealed a non-significant trend whereby non-users ($M=4.46$, $SE=.07$) had slightly worse delayed memory scores than past users ($M=4.80$, $SE=.11$, $p=.06$) and current occasional users ($M=5.32$, $SE=.35$, $p=.10$). Analyses

controlled for gender, $F(1,1231)=7.01$, $p<.01$, $\eta_p^2=.006$; education, $F(1,1231)=90.39$, $p<.001$, $\eta_p^2=.068$; age, $F(1,1231)=114.08$, $p<.001$, $\eta_p^2=.085$; and race $F(1,1231)=48.78$, $p<.001$, $\eta_p^2=.038$, found that cannabis use group was no longer associated with delayed memory, $F(3,1231)=1.74$, $p=.16$, $\eta_p^2=.004$.

Uncontrolled analyses suggested a significant main effect of cannabis use on working memory based on the serial sevens task $F(3,1344)=6.91$, $p<.001$, $\eta_p^2=.015$. Post hoc findings showed that non-users' ($M=3.35$, $SE = .06$) working memory was worse than both past users ($M = 3.72$, $SE = .09$) and current frequent users ($M = 4.0$, $SE = .18$; $p<.01$ for both). Given that serial sevens data were heavily skewed, this analysis was repeated using a Kruskal-Wallis nonparametric test. Interpretation of those results, $H(3)= 25.5$, $p<.001$, did not differ from interpretation of the ANOVA. Analyses controlled for gender, $F(1,1330)=14.92$, $p<.001$, $\eta_p^2=.01$; education, $F(1,1330)=165.44$, $p<.001$, $\eta_p^2=.11$; age $F(1,1330)=5.37$, $p<.05$, $\eta_p^2=.004$; and race $F(1,1330)=76.83$, $p<.001$, $\eta_p^2=.06$, found that cannabis use group was no longer associated with working memory $F(3,1330)=1.66$, $p=.17$, $\eta_p^2=.004$.

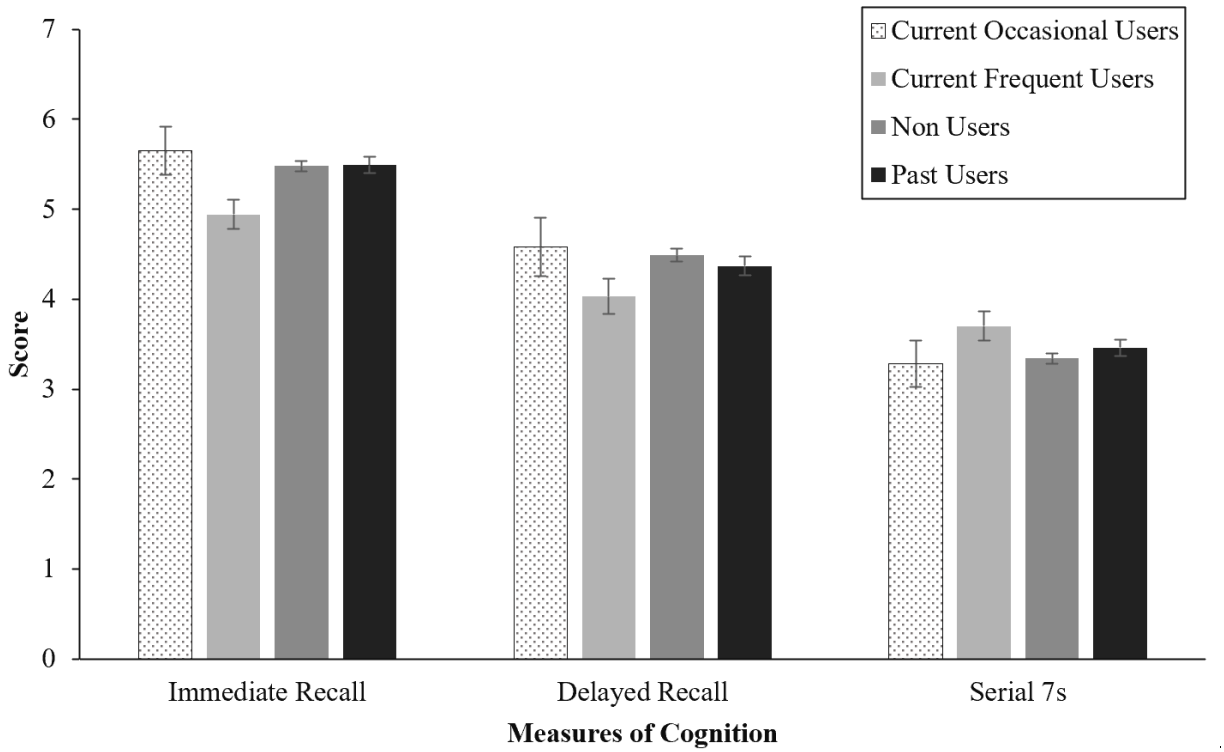

Figure 1. Summary of covariate adjusted means and standard errors of cognitive task scores for each cannabis use group.

DISCUSSION

This study aimed to examine two competing hypotheses about the relationship between cannabis use and immediate, delayed, and working memory in older adults. Uncontrolled analyses suggested an association between cannabis use status (current occasional, current frequent, past user, and non-user) and all three dimensions of cognition. However, controlling for age, gender, education, and race, cannabis use status was associated with immediate memory, but not delayed or working memory. Occasional (less than weekly) and past users, however, performed comparably to non-users on all measures of cognition evaluated in this study.

Frequent users' relative deficits in immediate memory may be explained by residual effects of cannabinoids in the system since these participants reported at least weekly use. Past research indicates that cognitive consequences of cannabis use can be attributed to residual cannabinoids or withdrawal, and appear to resolve with approximately 25 days of abstinence (Schreiner & Dunn, 2012). The frequent use group likely did not meet this threshold. The immediate free-recall task evaluates two primary cognitive components: attention and short-term episodic memory (Gavett & Horwitz, 2012). The finding that this measure can be used not only to characterize episodic memory but also attention can be attributed to the primacy-recency effect, which demonstrates that attention can increase scores on the immediate recall task (Gavett & Horwitz, 2012). In the current study, since both delayed and working memory were unaffected in older adult cannabis users, it is possible that these findings reflect attentional deficits that occur due to residual effects of cannabis, rather than memory deficits. However, these findings need confirmation through future studies.

While cognitive impairments seen in cannabis users are somewhat inconsistent across literature, overall, findings support the idea that attentional impairments are present with acute cannabis use and persist mainly as a residual effect (Broyd et al., 2016; Ganzer et al., 2016; National Academies of Sciences Engineering and Medicine, 2017). Deficits in immediate, delayed, and working memory may occur with acute use, and often resolve after periods of abstinence (Broyd et al., 2016; National Academies of Sciences Engineering and Medicine, 2017). Interestingly, aside from immediate memory, the current study contradicts past findings of delayed and working memory deficits, which may indicate that in older adults, these domains are somewhat unaffected by or resistant to the effects of cannabis. Future research is needed to further characterize these effects.

Given these results, older adults should be advised that frequent (at least weekly) cannabis use likely has negative effects on immediate memory. Due to the unclear parameters of cannabis use available for this study, this finding could be interpreted in two ways. It is presently unclear if poorer performance among frequent users is due to a cumulative effect on the central nervous system of high frequencies of cannabis consumption, or whether this effect reflects acute, recent cannabis intoxication. These results suggest, however somewhat inconclusively, that cognitive effects of frequent use may be mitigated by sustained abstinence over time. Older adults should consider that deficits in attention and short-term episodic memory may impede both social functioning (Faraone et al., 2000) and performance of tasks associated with independence, including driving (Barkley & Cox, 2007). However, the prominence of such effects in older adult populations needs corroboration through future studies which assess the practical application of such cognitive deficits. Current findings do not speak to perceived

quality of life in older adults and its association with cannabis use. Further, within the diverse population of older adults, given the various medicinal and recreational purposes of cannabis consumption, such cognitive impairments may be a tradeoff that some are willing to make. Older adults who are past cannabis users performed comparably to non-users and therefore may not need to consider past cannabis use as a threat to present cognitive functioning. Similarly, occasional (less than weekly) users do not differ from non-users, although this finding should be cautiously interpreted due to various limitations of the present study.

The primary limitation to this study was its sample size – although cannabis use was assessed among many respondents, cannabis use groups were largely variant in size, and only 2.7% of the sample identified as current occasional users. This study was also limited by the measures of cannabis use collected from respondents. Participants were asked if they had used cannabis within the past year, but nothing further denoting more recent cannabis use. Acute effects cannot be accounted for with such a large window of abstinence reported. Thus, indication of use within recent hours, days, and/or weeks may better differentiate use patterns and residual effects among current users (Schreiner & Dunn, 2012). Frequency of use was the only quantifiable dimension of cannabis use addressed in the Module 4 HRS data. If possible, future studies should also attempt to address dosage and/or cumulative lifetime use to further characterize cannabis use patterns. Finally, although the present study controlled for age, gender, race, and education, other control variables not addressed by this study may influence cognitive performance between groups.

Future research should seek to replicate and build on these findings, as well as control for additional potential confounds. Replication should include additional measures of attention and

memory to delineate the relationship between effects of residual cannabis and performance in each of these cognitive domains. With respect to cannabis use status, it would be beneficial to define cannabis use by participants' most recent use as well as frequency, dosage, and/or concentration of cannabinoids, if such data are available. Additionally, given adequate sample size, research addressing differences between more specified age groups of older adults is warranted. Finally, in addition to age, gender, education, and race, other demographic measures may be considered as controlled variables, in addition to certain mental health conditions that may be present in the sample. For instance, depression is known to negatively impact cognition in older adults (Lichtenberg et al., 1995) and this may account for some of the variance between cannabis use groups because Major Depressive Disorder may be a risk factor for problematic cannabis use (National Academies of Sciences Engineering and Medicine, 2017). Likewise, alcohol use should be considered and controlled for due to its known cognitive implications (Topiwala & Ebmeier, 2018) and the potential association of alcohol dependence and/or alcohol use disorder with cannabis use (National Academies of Sciences Engineering and Medicine, 2017). Taken together, these considerations would strengthen the validity of present findings.

With cannabis legalization at the forefront of imminent policy changes worldwide, a discussion of its implications on public health and wellbeing is warranted. Historically, the ability to obtain trustworthy research on the impact of cannabis on public health and safety has been severely limited by cannabis illegality and a consequential lack of funding. In combination with other works, the results of research can be used to better inform public health decision making. Findings of this nature can be used to help guide policy making involving cannabis use to minimize risk for both general and diverse populations, such as aging adults.

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