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Cue Reactivity of Marijuana Craving: An Investigation Examining Cognitive and Academic Impairment

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Abstract: Craving contributes to the development of substance disorders and is a significant factor leading to relapse. With the legalization of medicinal marijuana and retail marijuana in some states, understanding the effects of craving is essential. I designed an experiment to determine whether marijuana craving leads to cognitive and academic impairment among college students. I hypothesized that participants provided with a marijuana cue would demonstrate greater problems with working memory and reading comprehension than those assigned to a neutral cue control group. Eight university undergraduate students were recruited to participate. Though the study was underpowered, an effect size examining the impact of craving on reading comprehension suggested a moderate to high effect, with the marijuana group scoring lower than the neutral group. Data on the working memory task was skewed, thus limiting conclusions. The data was uninterpretable due to the small sample size, overall. With more research, findings will allow for a better understanding of the role of craving on university students.

Keywords: *marijuana craving, cognition, academics, college students*

Marijuana Use and Associated Consequences

Marijuana is the most commonly used drug in the United States, with approximately 18.9 million past month users in the nation (Substance Abuse and Mental Health Services Administration [SAMHSA], 2013). The number of individuals reporting marijuana use increased from 14.5 million to 18.9 million from 2007-2012 (from 5.8% to 7.3% of population). Daily users, as defined by SAMHSA (2013), are those who report smoking marijuana 20 or more days in the past month. Daily users have increased from 5.1 million users to 7.6 million users from 2007-2012. Use of marijuana by adolescents between the ages of 12 and 17 decreased from 2002 to 2006 and remained constant for two years since 2011. Marijuana use by adolescents increased to almost 8% (SAMHSA, 2013).

There are many factors that increase the risk of negative consequences for users. Some studies show that adolescent cannabis use can predict anxiety disorders and depression later in life (Brook, Rosen, & Brook, 2001). Marijuana use among daily users has been associated with suicidal ideation and interpersonal violence (Lynskey et al., 2004; Moore & Stuart, 2003). This can be seen in adults but risk is higher with adolescent users. Furthermore, Veen et al. (2004) found that the first signs of schizophrenia were seen much earlier among individuals who used marijuana heavily. These signs of schizophrenia included: social or work dysfunction, first psychotic episode, and negative symptoms (lack of emotions, flat affect, or no eye contact) Males suffering from schizophrenia who are marijuana smokers tend to show signs as much as 6.9 years earlier than the average age of onset (Veen et al., 2004).

Heavy marijuana users (defined as those who use marijuana more than 7 times in a week) often report lower satisfaction in life, poorer mental and physical health, more relationship problems, and lower academic and career success compared to people of similar backgrounds who don't use marijuana (Volkow et al., 2014). Furthermore, in the work environment, marijuana use increases instances of being absent or late, workplace accidents, and claims for worker's compensation, which lead to worker termination from employment (Crouch, Webb, Peterson, Buller, & Rollins, 1989).

Memory, working memory, and attention are also affected by chronic, heavy marijuana use (Pope, Gruber, & Yurgelun-Todd, 1995; Solowij & Pesa, 2010; Shrivastava, Johnston, & Tsuang, 2011). Students who are heavy smokers may

struggle to learn new material. Pope and Yurgelun-Todd (1996) found that college students who use marijuana regularly have impaired attention, memory, and learning for up to a day after using. In their review of the impact of marijuana on cognitive functioning, Solowij and Pesa (2010) found that, during acute intoxication, the individual will experience perceptual distortion, difficulty concentrating, and impaired memory.

When areas such as working memory, attention, and memory are affected, academic performance will likely suffer (Pope et al., 1995). Cannabis use at an early age is associated with lower academic success (Pope et al, 1995). Chronic marijuana users are less likely to complete high school, enroll in college, or complete a college degree (Fergusson, Horwood, & Beautrais, 2003; Horwood et al., 2010). Fergusson et al. (2003) examined whether low academic achievement leads to increased marijuana use. Their findings were more consistent with a one-way model that shows that marijuana use leads to problems in school. Some common academic problems associated with marijuana use include increased absences, lower GPA, and negative attitudes towards education (Lynskey & Hall, 2000).

Substance Use Craving

Marijuana craving is a contributing factor to cannabis use disorders. Drug craving has been defined as "the experience of an intense or compelling urge or desire" to use a substance (Rosenberg, 2009, p. 2). The individual's subjective interpretation of stimuli from previous experience can induce a desire to want to use the drug (Drummond, 2000). Even during a period of nonuse for months or years, the desire or craving for a drug can be triggered. Individuals with substance disorders have a difficult time remaining abstinent (Tiffany & Conklin, 2000) and craving is one of the most significant factors contributing to relapse. Craving can elicit memories, such as thoughts and images of the user's former substance-use lifestyle, which may increase desire to use in these specific situations (Tiffany & Conklin, 2000).

Three craving theories have attempted to explain how craving operates: drug withdrawal models, positive-incentive models, and the cognitive processing model (Tiffany & Conklin, 2000). Drug withdrawal models indicate that a drug will be paired with stimuli to elicit a conditioned withdrawal effect. These effects are presumed to mimic a component in the autonomic system of drug withdrawal to generate drug craving. As an example, consider an individual who sees a bar or smoke shop that they previously associated with their substance use. The location serves as a stimulus that has been conditioned over time and activates a withdrawal effect in the brain. This withdrawal leads to physical consequences, such as sweating, rapid pulse rate, and autonomic hyperactivity, as well as a desire to seek out the drug (Tiffany & Conklin, 2000).

Positive-incentive models propose that drug-paired stimuli become incentives conditioned to activate the central motivational state (Tiffany & Conklin, 2000). The state of craving generates drug-use behavior and an autonomic response, consistent with direct effects of the drug. When a user encounters an environmental cue, such as a sign of a bar, this elicits cravings and approach behavior. This incentive stimulus (i.e., the sign) draws the user in like a magnet and leads to further exposure associated with drugs. This cascade effect contributes to an eventual relapse.

A major difference between positive-incentive models and withdrawal models is the autonomic reactions that cause the craving. The positive-incentive models assume that there is a direct activation effect of the substance. Withdrawal models make use of withdrawal effects of the substance leading to craving. The significant problem with these models is the assumption that the autonomic system activates craving. Past studies examining the relationship between craving and autonomic measures show little correlation between the two variables (Tiffany & Conklin, 2000), leading to speculation that craving operates on an unconscious level. It is

possible that craving may serve as a contributing factor of substance-use, among those addicted, or as an epiphenomenon, meaning that craving may function as a secondary phenomenon that accompanies substance use and relapse. In this latter manner, craving may react to the operation of drug processes that are important to addictive disorders (Tiffany & Conklin, 2000).

The Cognitive Processing Model proposes that the activation and processing of craving is independent from the regulation of drug use in heavy users (Tiffany & Conklin, 2000). Drug use itself is thought to be an automatic process that can become effortless, and the actions of drinking, smoking, etc. soon become part of the individual's lifestyle. Such habits, like other areas of automatic processes, begin to direct our attention. There are a few main features of automatic processes. Firstly, the actions have to be practiced repeatedly and this will eventually allow the action to be smoother, faster, and less effortful. The second feature of automatic processing is the stimulus associated with the action. Every action is done for a reason, with markers that indicate when to execute an action. The automatic processes are eventually performed when the right stimuli are present, contributing to little control. Lastly, the automatic process becomes so effortless that there becomes less demand of cognitive resources. Essentially, individuals begin to see an orchestra of automatized actions that can happen together without much thought. Common examples of automatic processes would include walking, reading, and speaking. All of these are learned, but feel fairly automatic.

Alternatively, craving is considered a non-automatic process that is triggered either for those trying to remain abstinent, or for those who desire to use their substance of choice but encounter an obstacle to their use (Tiffany & Conklin, 2000). When faced with craving, the individual who wants to use must determine, via non-automatic processing, how to overcome the barrier. The person who is trying to remain abstinent must employ mental effort to avoid using his or her substance. In both situations, the increased cognitive effort associated with craving may interfere with other cognitively demanding tasks.

Considering the Cognitive Processing Model, it is important to determine how craving may impact working memory and other cognitive processes (Tiffany & Conklin, 2000). Working memory is important due to its role in organizing information that comes into the brain, which contributes to successful learning (Mathias, 1996). The working memory system prioritizes information and processes it into the memory system, making it possible to do math calculations and engage in and comprehend conversations (Fisk & Montgomery, 2008). Furthermore, attention is affected when an individual is induced to crave, thus using other cognitive resources. This additional workload prohibits new information from being placed into long-term memory (Fisk & Montgomery, 2008; Mathias, 1996, Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007). As will be discussed, increased craving may impact important processes that are needed to succeed in the college environment.

Cue Reactivity

The notion of cue reactivity was formed from observations from Wikler (1948), who noted that addiction was being reinforced, causing people to relapse from environmental cues. Cue reactivity can be triggered by various domains of expression, such as feelings (e.g., frustration, need, anxiety), cognitive experiences (e.g., dreams, imagined images, thoughts of using, anticipation of using), behaviors (e.g., using drugs quickly, working to purchase or acquire drugs), and psychophysiological processes (e.g., sweaty palms, excessive saliva, increased blood pressure) (Rosenberg, 2009). These multi-level experiences make identifying the roots of desire hard to define. This observation can be seen in both human and animal studies. Because environmental cues activate our basic five senses, researchers have been able to measure craving through cue-reactivity designs.

Visual cue reactivity induces craving through videos and pictures depicting different substances (e.g., cigarettes, alcohol, and marijuana) or

substance paraphernalia. Participants are asked to look at pictures or watch videos of the substance and other associated cues related to their drug of choice (Gray, LaRowe, & Upadhyaya, 2008; Lundahl & Johanson, 2011; Shiffman et al., 2013; Meule, Skirde, Freund, Vögele, & Kübler, 2012). Auditory cues have also been used to cue craving and often consist of participants listening to a scenario related to their substance of choice. This type of cue is often referred to as an auditory script (Heishman et al., 2006; Madden & Zwaan, 2001). Use of olfactory cues have been demonstrated in a study by Loflin and Earleywine (2013), where participants completed a word association task after smelling cannabis sativa oil. This oil was used to mimic the scent of marijuana and induce craving. The neutral group was given a cup that contained a cotton ball with no scent. The study showed a higher number of words associated with marijuana in the group induced to crave.

The last type of cue-reactivity involves in-vivo cues, where participants touch and feel items related to their substance of choice. This type of cue has been used in marijuana and food craving studies (Gray et al., 2008; Gray, LaRowe, Watson, & Carpenter, 2011; Lundahl & Johanson, 2011; Kemps, Tiggemann, & Grigg, 2008). All of the different in-vivo cues have effectively induced craving.

When a person uses drugs, they are initiating memories and creating impressions. These impressions are then stored in the memory from individuals' senses (Caplan & Waters, 1999). The way people become intoxicated on a drug can also become a preference. There are multiple ways to become intoxicated, with some methods proving to be faster than others and some leading to a stronger high. Other times it may be just sociocultural commonality to use the drug in a certain way (Drummond, 2000). It is important to consider individual differences, as certain types of cue-reactivity may impact some individuals more than others (Drummond, 2000).

Although not thoroughly researched, certain types of cue reactivity appear to operate through different neurocognitive mechanisms. For example, the hippocampal region of the brain, involved in memory with olfactory cues, connects smells to individual patterns in the memory (Giorgi, Maggio, & Bruni, 2011). Cue reactivity for visual stimuli operates through working memory, which is used to receive and store information about the environment. Working memory is central to all incoming information because it allows the facilitation of new information to store in long-term memory or integrate with old information. In-vivo cue reactivity often includes a mixture of visual, touch, and auditory cues (Gray et al., 2008). This type of cue-reactivity tries to replicate substance use by allowing the participant to handle materials related to the drug. In marijuana studies, this might include touching a lighter, holding paper rolls that are used to make a blunt, or looking at a bong. Typically the more senses being stimulated to prime thoughts, the greater the chance of inducing craving.

Cue reactivity studies have demonstrated a range of impairments related to memory, working memory, and attention, when craving is induced (Sayette, Schooler, & Reichle, 2010; Heishman et al., 2006; Meule et al., 2012; Madden & Zwaan, 2001). Sayette et al. (2010) conducted a study on cigarette craving and the ability to sustain attention in a reading task. As part of the study's eligibility, participants needed to have a particular carbon monoxide (CO) level that demonstrated that they had not smoked. Participants were assigned to one of two conditions – a craving condition that included cue reactivity or a low craving, neutral condition. Those in the low craving condition were allowed to smoke a cigarette during the study after each task was given. Both groups were given the same tasks, which included a color naming task that examined the impact of craving on subliminal perception. Once this task was done, the control group was allowed to smoke. The two groups had their CO levels measured again and were asked to complete a nicotine dependence test, as well as a demographic form, and an urge questionnaire. Both groups were then asked to read a novel and

indicate whenever they felt themselves zoning out. The researchers found that those in the craving condition zoned out three times more than those in the low crave condition. This data suggests that sustained attention and meta-awareness were disrupted due to nicotine craving.

The assessment of cognitive impairment after cue exposure has also been used in other cigarette studies and with food studies (Heishman et al., 2006; Meule et al., 2012; Madden & Zwaan, 2001). These studies have found that working memory is impacted by craving. Researchers hypothesize that this impairment is due to cognitive resources being depleted as thoughts about using the substance start to appear (Kemps, Tiggemann, & Grigg, 2008). This is significant because long-term memories are retained in working memory when individuals need to recall important information. People can hold previous information as they complete a task or integrate new information. A person with a substance-use disorder has memories of using and experiencing the drug. During this moment of craving, cognitive resources are being used and new information cannot be processed, leading to lower retention of memory and poor attention (Barrouillet et al., 2007).

Purpose

The purpose of this study is to examine the impact of marijuana craving on cognitive and academic performance. A number of past studies with other substances have demonstrated that cue exposure can induce craving, and that craving will produce cognitive impairment. Studies on marijuana have shown that it is possible to induce craving with a range of different cues (Loflin & Earleywine, 2013; Grusser, Heinz, & Flor, 2000; Gray et al., 2008). However, past studies have not manipulated marijuana craving to examine its impact on cognitive performance. I aimed to design an experiment to help determine whether marijuana craving leads to cognitive impairment. I hypothesized that marijuana users randomized to a marijuana cue group would demonstrate greater deficits in working memory and reading comprehension compared to marijuana users randomized to a neutral cue group.

METHOD

Participants

Participants included students enrolled in an Introduction to Psychology course who completed research credits for their class. Students were recruited after they completed participation in another study on marijuana use. Participants in that study, referred to as "Phase 1," completed a series of questionnaires assessing marijuana and other substance use, as well as information about academics, and a range of psychological variables. Some of this Phase 1 data was used in the current study to describe participants' demographics, marijuana usage, and other drug use. Phase 1 participants completed a urine screen to determine if they had used marijuana over the past few weeks. After participants completed the urine screen, those who tested positive for marijuana were asked if they would like to receive an additional two credits to participate in the current study. Those who agreed to participate were scheduled for an appointment in the lab.

The target sample size for the current study was 49 students. A power analysis using G power (Faul et al., 2007) suggested a sample size of 49 was appropriate for an exploratory study, such as the one being proposed (power = .70, effect size = .30). Due to time constraints, it was not possible to recruit 49 participants into the study.

Procedures

The current study used an experimental design, with random assignment of participants to one of two groups (marijuana craving condition or neutral control condition). Marijuana craving was the independent variable, while working memory and reading comprehension were dependent variables. This study was submitted to and approved by the IRB.

Participants presented to the lab and completed informed consent. They were then asked to complete two tasks: the Letter Word Identification Test (Woodcock, McGrew, &

Mather, 2001) and the Letter Number Sequencing Test (Wechsler, 1997). Following these tasks, participants completed two separate Visual Analog Scales (VAS), which documented their mood and level of craving. Participants were then randomized into one of the two groups. One group was cued to crave marijuana and the other group was a control group presented with a neutral cue. To cue marijuana craving, a slideshow with marijuana and marijuana-related content was shown to participants. This slideshow included an audio narrative that lasted 90-seconds. The control group viewed a similar 90-second slideshow, but the content focused on vegetables instead of marijuana.

Once the participants finished viewing the slideshow, they were asked to complete a working memory task called the N-Back (Jaeggi, 2010). They then watched their respective cue slideshow a second time. Finally, they completed a reading comprehension task called the Nelson Denny (Nelson & Denny, 1960. Once these tasks were completed, participants again completed the craving and mood VAS scales, as well as the Marijuana Craving Questionnaire (MCQ-BF; Heishman et al., 2009).

Participants in the Marijuana Cue Group who rated their level of craving between 8 and 10 on the final VAS scale were asked to sit in the lab for 5-10 minutes and watch a relaxation video. All participants were debriefed about the study's goals and any participants who were interested in referral information for counseling were given contact information for the University Counseling Center, the University Psychological Services Clinic, and an outpatient treatment facility.

Measures and Tasks

Demographics. Participant data from Phase I of the study were available for analyses. Gender, age, relationship status, ethnicity/race, college status, and living situation were collected.

Cannabis Use Disorder Identification Test Revised (CUDIT-R; Adamson et al., 2010). The CUDIT-R is a brief 8-item measure that has demonstrated efficiency, reliability, and validity in screening for problematic marijuana use. CUDIT data was collected during Phase I and available for data analyses.

Mood and Craving Visual Analog Scales (VAS). Participants were presented with a visual analog scale (VAS) and instructed to place a vertical mark that best described their current mood, using the prompt: *"Please rate your current mood on a scale of 0-10, with 0 being "low/negative mood" and 10 being "high/pleasant mood."* A VAS item that specifically addressed craving for marijuana included the phrase: *"How strong is your craving for marijuana right now?"* Responses were recorded identically to the mood item described above on a 0-10 scale.

Marijuana Craving Questionnaire, Short Form (MCQ-SF; Heishman et al., 2009). Marijuana craving was assessed using the Marijuana Craving Questionnaire-Brief Form (MCQ-BF). The MCQ-SF has 12 items thought to represent four specific constructs that characterize marijuana craving.

Cue Reactivity/Exposure Stimuli

Marijuana Cue. The 90-second marijuana cue included both visual and auditory components. Participants watched a slideshow of photos with marijuana and marijuana-related content. As they watched this slideshow, an audio narrative was played that described, in second person, a scenario about smoking marijuana with friends at a party.

Neutral Cue. The 90-second neutral (vegetable) cue included both visual and auditory components. This cue included a slideshow with vegetables and content that follows an audio narrative describing, in second person, someone who is eating vegetables with friends at a party.

Cognitive Tasks

Letter-Number Sequencing (subtest from WAIS-III; Wechsler, 1997). This task assessed working memory. Participants read a sequence of letters and numbers and were asked to repeat them back in alphabetical and numerical order (e.g., L195TA would be ALT159).

N-Back. The N-Back task is a well-validated test of working memory (i.e. one's ability to hold and manipulate information online) (Jaeggi, 2010). In this task, participants watched a computer screen as the display showed a series of digits, displayed one at a time. The participant was asked to indicate, by button press, when a digit had previously appeared a certain number of places back. For the purposes of this study, the total percentage of correct items on both the 2- and 3-back tasks was used.

Academic Tasks

Letter Word Identification Test (subtest from Woodcock-Johnson, 3rd edition; Woodcock, McGrew, & Mather, 2001). In this task, participants were asked to name letters and read words aloud from a list.

Nelson-Denny Reading Test (Nelson & Denny, 1960). This 20-minute reading comprehension test includes five brief passages taken from high school and college textbooks. Participants read each passage and then answered multiple-choice questions testing their understanding of the passages. For the purposes of this study, the total percentage of correct items was used.

Data Analysis

All data was entered into SPSS (version 22). Although between-group analyses (either a MANOVA or a MANCOVA) were initially planned to compare scores between the neutral control and marijuana cue groups, 49 participants were not recruited. Instead, eight participants completed the study. Due to this low sample size, all analyses focused on presenting descriptive data, calculating effect sizes, and examining trends.

RESULTS

Demographics

A total of eight college students completed the study, including seven males and one female. Five participants were randomly assigned to the marijuana cue group and three to the neutral cue group. The average age of participants was 19.00 (*SD* = 0.69). Mean cumulative GPA was 2.80 (*SD* = .75). Students were well represented by major, with two business majors, two undeclared majors, and one student each from communication, nursing, software engineering, and sports and exercise. Additional participant demographics are presented in Table 1.

Drug Use

Table 1 also includes participant drug use history. Of note, participants began using marijuana at a mean age of 15.13 (*SD* = 1.73) years. Participants were heavy marijuana smokers, with average use of 21 days (*SD* = 10.27) out of the last 30. Three participants reported smoking every day and three additional participants reported smoking 15 or more days in the last month. Three participants reported medical marijuana prescription use, which is legal in the state of Colorado.

Impact of Cue Stimuli on Craving and Mood

To examine the impact of the cue reactivity stimuli on participant craving and mood, mean scores on the post-craving and post-mood VAS scales were compared between the groups. All of these measures were given after the cue reactivity.

Post-craving VAS scores were comparable between the two groups (see Table 2). Participants in the neutral cue group indicated a slightly higher craving level (*M* = 2.67, *SD* = 2.89) compared to participants in the marijuana cue group (*M* = 2.00, *SD* = 2.35). Post-mood means showed that the neutral cue group scored slightly lower (*M* = 6.33, *SD* = 2.08) than the marijuana cue group (*M* = 6.40, *SD*=1.67).

Cue Reactivity

To assess the impact of cue reactivity on cognitive and academic performance, the Nelson-Denny and the N-Back test scores were examined. I hypothesized that the marijuana cue group would perform lower on both of these tasks compared to the neutral cue group.

When examining means from the Nelson-Denny reading task, participants in the marijuana cue group scored lower (*M* = 25.80, *SD* = 2.49) than participants in the neutral cue group (*M* =

Table 1. Demographics and Drug Use (n = 8) (Continued on next page)

Measure		***N***	**Percentage (%)**	***M* (*SD*)**
Gender	Male	7.00	87.50	
	Female	1.00	12.50	
Age	18.00	2.00	25.00	19 (0.69)
	19.00	4.00	50.00	
	20.00	2.00	25.00	
Major	Business	2.00	25.00	
	Communication	1.00	12.50	
	Nursing	1.00	12.50	
	Software Engineering	1.00	12.50	
	Sports & Exercise	1.00	12.50	
	Undecided	2.00	25.00	
Age of first use	13	1.00		15.13(1.73)
	14	3.00		
	15	1.00		
	16	1.00		
	17	1.00		
	18	1.00		
Days used marijuana in last 30 days				
6	1.00	12.50		21(10.27)
8	1.00	12.50		
15	1.00	12.50		
20	1.00	12.50		
29	1.00	12.50		
30	3.00	37.50		
Are you prescribed medicinal marijuana?				
Yes	3.00	37.50		
No	5.00	62.50		
Do you also use marijuana for recreational purposes?				
Yes	2.00	25.00		
No	1.00	12.50		
Total	3.00	37.50		
System	5.00	62.50		
Frequency				
2-3 times per month	1.00	12.50		
2 days per week	1.00	12.50		
4 days per week	1.00	12.50		
5 days per week	1.00	12.50		
Every day	2.00	25.00		
More than once a day	2.00	25.00		

Table 1. Continued

How old were you when you first tried marijuana?			
13	1.00	12.50	15.13(1.73)
14	3.00	37.50	
15	1.00	12.50	
16	1.00	12.50	
17	1.00	12.50	
18	1.00	12.50	

Table 2. Cue Reactivity of Marijuana Craving.

Measure	**Group Assignment**	
	Marijuana Cue Group *M* (*SD*), *n* = 5	Neutral Cue Group *M* (*SD*), *n* = 3
Letter number	11.6 (2.79)	13.33 (2.89)
Letter word	13 (3.81)	14.33 (2.52)
Nelson Denny	25.8 (2.49)	27.67 (2.31)
Pre-Mood VAS	6.6 (3.13)	5.33 (1.53)
Post-Mood VAS	6.4 (1.67)	6.33 (2.08)
Pre-Craving	1.6 (1.82)	2 (2.65)
Post-Craving	2 (2.35)	2.67 (2.89)
N-Back (2 & 3)	52.7 (24.36)	45 (23.43)
MCQ Factor 1: Compulsivity	14.2 (5.5)	11.67 (8.14)
MCQ Factor 2: Emotionality	4.2 (1.64)	4 (1.73)
MCQ Factor 3: Expectancy	5.6 (2.88)	5 (3.46)
MCQ Factor 4: Purposefulness	11.8 (3.42)	11 (1.73)

27.67, *SD* = 2.31). This was in the expected direction. An effect size was calculated to compare these scores due to not having enough participants to conduct statistical analyses. A Cohen's *d* of .78 was found, indicating a medium to large effect (Cohen, 1988).

On the N-back (working memory) task, participants in the marijuana cue group scored higher (*M* = 52.70, *SD* = 24.36) than participants in the neutral cue group (*M* = 45.00, *SD* = 23.43). This was not in the hypothesized direction. Scores from all participants were examined for outliers. Upon observation of the N-back data, one outlier was found within the marijuana group. This participant scored 81.50 (*SD* = 0.71) on the test, much higher than the other participants. Because this score was significantly higher, this participant was removed to examine an effect size. After removing the outlier, the mean N-back score in the marijuana cue group was 45.50 (*SD* = 21.1), still slightly higher than scores in the neutral cue group (*M* = 45.00, *SD* = 23.43). An effect size was not calculated due to the lack of meaning in such findings. Results from the N-back and Nelson-Denny condition analyses are displayed in Figure 1.

DISCUSSION

The goal of this research study was to see if marijuana craving disrupts cognitive and

academic performance. This is important because craving is one of many factors involved in addiction. The data indicated that there were some trends in line with the study hypotheses. Because the ideal sample size was not attained, effect sizes were calculated. Scores on the Nelson-Denny Reading Test indicated a medium to large effect size. The N-back assessing working memory showed an opposite trend than what was predicted where the neutral group scored lower than the marijuana group. An outlier appeared to be skewing the data, so this participant was excluded. Even after excluding this participant, mean scores were similar. Scores on both the N-back and Nelson-Denny demonstrated high variability, thus limiting any conclusions. These relationships indicate that further research should be explored to see if any patterns emerge with a larger sample size.

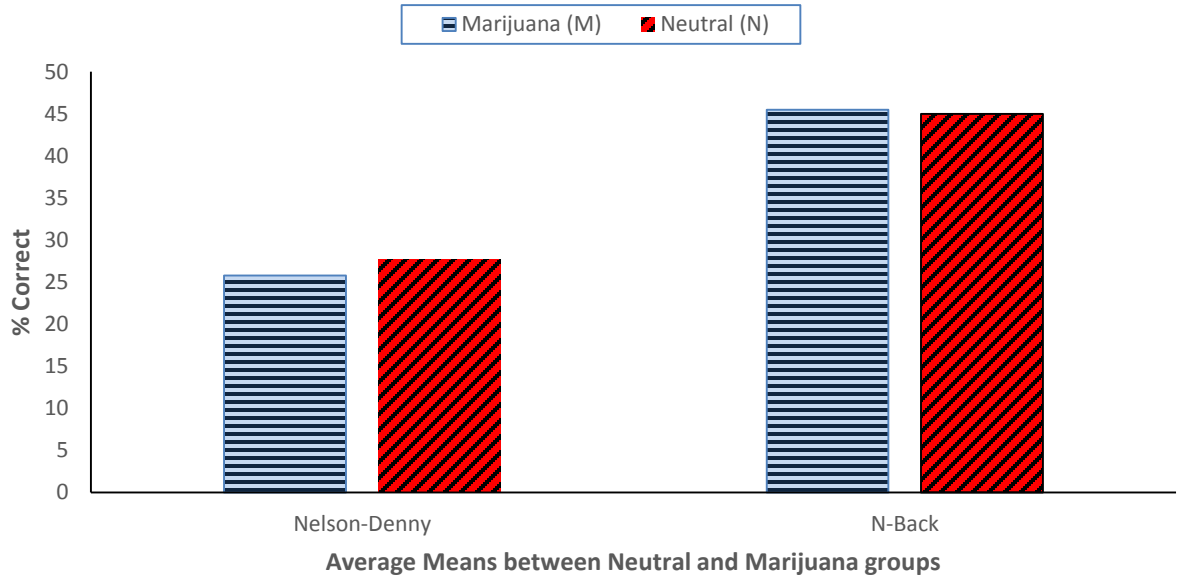

Figure 1. Mean scores on N-Back and Nelson Denny reading task between Neutral Cue and Marijuana Cue groups (n = 7).

Past research on craving in other areas, such as cigarette and food craving, has shown that craving can impact cognition (e.g., working memory, memory, attention, cognitive load) and academic performance. Such research suggests that attention is impacted when cue stimuli are present. This is due to the reinforcement of craving that triggers illicit thoughts about using. These thoughts expend our cognitive load and direct our attention elsewhere. In a study conducted by Heishman and colleagues (2006), the impact of craving on memory encoding and retrieval was investigated among cigarette smokers. The researchers found that participants were unable to encode information during craving, and this makes new information harder to comprehend. They did not see any impact on recalling information to mind from previously learned information. This is how craving can impact cognition and academic performance.

Although past studies have found that it is possible to induce craving using cue-reactivity, no one has assessed whether marijuana craving impacts cognitive or academic performance. The current study was able to assess this by using a visual/auditory cue to induce craving in order to examine its impact on working memory and reading comprehension. Only one past study (Sayette, Schooler, & Reichle, 2010) examined the impact of nicotine craving on reading comprehension. Participants in the Sayette, et al. (2010) study were asked to read 34 pages from a novel for 30 minutes. The researchers found a

proportional relationship between level of craving and zoning out, in that the higher the level of craving, the more "zoned out" participants in the cue group were. In the current study, participants in the marijuana group performed more poorly than the neutral group on the Nelson-Denny reading task. This trend in the data suggests that craving may have an effect on academic performance.

One limitation for this study was the sample size. With only eight participants, we were only able to calculate an effect size, which is impacted by the wide variation in the data. The goal of the study was to recruit 49 participants. Therefore, statistical comparisons could not be made due to limited power. There were many variables that could not be controlled with only eight participants. The one-item VAS ratings for mood and craving indicated similar ratings between groups, so it is possible that the cue-reactivity protocol may not have been effective in inducing craving. Craving is fragile in nature and subjective to the individual, so it is possible that the cue stimulus was not effective. Lastly, demographics of participants in terms of gender, race/ethnicity, and major may not generalize to the general population.

Future researchers may want to explore similar hypotheses using a larger sample size in order to test data statistically and have more control of confounding variables that could influence the data. It would also be useful to determine the most effective type of stimuli to induce marijuana craving. It is possible that some combination of olfactory, visual, auditory, and in-vivo cue might be most effective.

In conclusion, this study attempted to examine the impact of marijuana craving on cognitive and academic performance. A moderate to high effect was found for the impact of marijuana craving on reading comprehension. This indicates a trend that supports my hypothesis, though a larger sample size is required to form any firm conclusion. This research is important to conduct in order to better understand how craving may impact cognitive and academic performance among college students. If craving negatively impacts attention, working memory, and short/long term memory, students using marijuana may perform poorly in the academic setting. More research would better inform interventions with college students.

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