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CANNABIS LEGALIZATION: UNDERSTANDING HOW EVOLVING POLICY LANDSCAPES AFFECT EMERGING ADULTS' CANNABIS-RELATED BEHAVIORS IN THE US

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Abstract

Background

An increasing number of US states have legalized cannabis for recreational, or adult, use, where access to cannabis products is limited only by age. The largest proportion of cannabis users are among emerging adults (EAs) compared to younger and older people. EAs are a unique population group, transitioning from adolescence into adulthood, where substance use experimentation is more common than in other life stages; therefore, it is important to understand the effects of cannabis legalization on this group.

Purpose

The three objectives of this dissertation were to 1) map and summarize the scientific literature on cannabis advertising effects on perceptions and behaviors, 2) describe cannabis use behaviors among EAs in the US and compare use behaviors in states with and without adult-use legal sales and among EAs under (18-20 years old) and over (21-25 years old) the legal age to purchase cannabis, and 3) test the effects of cannabis advertising stress relief messaging on cannabis-related perceptions and intentions among EAs who are under the legal age to purchase cannabis (18-20 years old).

Methods

In study one, scoping review methods were used to map and summarize the scientific literature on cannabis industry advertising effects on cannabis-related perceptions, beliefs, attitudes, and behaviors. In study two, a cross-sectional study design was used to understand EAs' cannabis use patterns by adult-use legal sales status and age group. A subsample of EAs from the 2021 US data were drawn from the International Cannabis Policy Study (ICPS) (n=3,467), an online survey administered annually that identifies the impacts of cannabis legalization on cannabis perceptions, use, and retail sales. EAs' use frequency, mode, multi-modal use, cannabis source, and source legality were described and differences by state legality and age group were analyzed using adjusted logistic and linear regression. In study three, participants aged 18-20 years participated in a between groups eye tracking experiment, where they were randomized to a control (cannabis availability messaging) or an experimental (stress relief messaging) group to view cannabis ads. Pre-appointment survey, eye tracking, and post-survey data were collected. To understand any differences, group means were compared and linear regression was used to understand the association between the eye tracking measures and perception outcomes.

Results

Study one

There were 17 studies that fit the eligibility criteria which were charted and summarized using two themes: *cannabis-related perceptions, attitudes, and beliefs* and *cannabis-related intentions and behaviors*. Most studies used cross-sectional designs and participant self-reported recall to measure advertising exposure. The majority of studies found that cannabis advertising exposure was associated with positive cannabis-related perceptions, attitudes, and use behaviors.

Study two

Among EAs aged 18-25 years old, 33% (95% CI: 30.9, 35.2) used cannabis in the past 12-months (P12M) and half reported being a never user. Among P12M users (n=1,248), over-age EAs (21-25 years old) in legal states had higher odds of using multiple modes of use (aOR 1.34; 95% CI: 1.04, 1.72) than over-age EAs in non-legal states. Both under-(18-20 years old) and over-age EAs in legal states had higher odds of obtaining cannabis from a dispensary than in non-legal states (aOR 2.14; 95% CI: 1.31, 3.48 and aOR 6.02; 95% CI: 4.40, 8.24, respectively). Over-age EAs in legal states had lower odds of obtaining cannabis from a dealer than over-age EAs in non-legal states (aOR 0.3; 95% CI: 0.24, 0.44). Under-age EAs in legal states who used cannabis concentrates used them on almost 34 more days in the P12M than under-age EAs in non-legal states (95% CI: 10.33, 56.21). All EAs in legal states reported obtaining almost 25% more legally sourced cannabis in the P12M than EAs in non-legal states (95% CI: 19.32, 29.94).

Study three

There were 90 participants who viewed the ads; overall, no group differences were found for the eye tracking fixation data nor for the perception outcomes. The results from the linear regressions showed that longer fixation duration on the stress relief messaging (experimental group) was associated with increased belief in stress relief (β=0.39; p=0.0285), lowered harm perceptions (β=-0.61; p=0.0016), and greater intention to use (β=0.87; p=0.0021). No associations between fixations and the perception outcomes were found in the cannabis availability messaging group. Additionally, the stress relief messaging lowered harm perceptions among non-past 30-day (P30D) cannabis users while the cannabis availability messaging had no effect on non-P30D users (2.35 vs. 2.71, p=0.0550).

Conclusions

Understanding the effects from legalization on EAs' perceptions and behaviors is vital for informing future research and state policy. The research presented in this dissertation shows that cannabis advertising exposure, such as billboards, print ads, and internet ads, affects perceptions, attitudes, and behaviors. EAs' cannabis use patterns are also associated with adult-use legal sales in the US, where under-age EAs in states with legal sales reported more concentrated cannabis use and greater access to legal cannabis dispensaries and products. These findings suggest that increased access to cannabis through the legal marketplace and perceived normalization of use in the US

might be mechanisms driving increases in use, particularly use of concentrates. Additionally, the eye tracking experiment revealed that among under-age EAs, there was an association between longer fixation times on the stress relief messaging and increased belief in stress relief, lowered harm, and greater intentions to use. Future studies could investigate the influence of health and wellness advertising messaging on cannabis-related perceptions and behaviors. Eye tracking technology may be a particularly useful tool for understanding viewing patterns for ads in general or for specific messaging. Research studies could also explore under-age EAs' experiences obtaining cannabis and their perceptions on the social norms related to use. Policy recommendations include addressing cannabis advertising density in an effort to reduce exposure and limiting stress relief messaging on cannabis advertisements due to the potential influence on under-age EAs. Often, cannabis regulations aim to limit advertising appeal and subsequently, use, among youth and children. Therefore, policies that expand their definitions of appeal to include those of older adolescents and EAs would offer greater protection from influential messaging, thereby reducing harm among a population at increased risk of use.

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Contents

List of Tables

List of Figures

CHAPTER ONE: INTRODUCTION

Introduction and Specific Aims

According to the Substance Abuse and Mental Health Services Administration (SAMHSA), 13% (36.4 million) of people in the US aged 12 years and older used cannabis in the past month in 2021 (SAMHSA, 2022). Emerging adults (EAs) aged 18-25 years had the highest percentage of past month cannabis use compared to people older or younger, with 24.1%, or 8.1 million EAs who used cannabis, which included 6.5%, or 2.2 million EAs who vaped cannabis (SAMHSA, 2022). In addition, 14.4% (4.8 million) EAs reported having cannabis use disorder (CUD) in the past year, which was higher than the reported percentages of CUD for both adolescents aged 12-17 and people 26 years old and older (SAMHSA, 2022). In addition to use behaviors, EAs were less likely to perceive harm from weekly cannabis smoking compared to people younger or older (SAMHSA, 2022).

Cannabis legalization is implemented through multiple policies throughout the US, with most states having multiple legalization laws. Many states have enacted laws to expunge prior cannabis-related convictions and decriminalize cannabis, allowing possession of small quantities of cannabis without penalty from the law (NCSL, 2022). A few states have authorized sales of low-THC products only, which does not require a comprehensive medical cannabis program in the state (NCSL, 2023). As of 2023, there are 38 states that have medical cannabis programs, requiring program registration and a

state-approved medical health issue in order to purchase products (NCSL, 2023). Twenty-four states have non-medical, or adult-use laws in the US, which only require age verification for purchasing cannabis. There are only three states in the US that have no legal cannabis access programs (NCSL, 2023).

Adult-use legalization results in initiation of retail sales, subsequent advertising of products directly to consumers, and increased access and availability of products through dispensaries or retail stores. These aspects of legalization are also associated with cannabis-related perceptions and behaviors. Among adolescents, greater dispensary density and exposure to advertising were associated with increased cannabis use and intentions to use (Borodovsky et al., 2017; D'Amico et al., 2015). Compared to before adult-use cannabis sales were implemented in states, adolescents perceived cannabis easier to access after implementation of sales (Harpin et al., 2018). Among EAs, cannabis dispensary density is associated with increased perceived ease of access, cannabis use, frequent use, and intentions to use (Pedersen et al., 2021; Rhew et al., 2022). Among adults, cannabis advertising exposure is greater in states with legal cannabis sales and increased exposure to advertising is associated with greater dispensary proximity and increased use frequency (Rup et al., 2020).

EAs are in a particularly vulnerable stage of life for initiating use and developing substance use patterns. Emerging adulthood is a transitional stage where people emerge from adolescence and enter adulthood and experimentation with substances can be a normal part of this process (Arnett, 2005). Substance use during emerging

adulthood can also escalate, which can lead to more established use patterns that are sustained into adulthood (Villanti et al., 2019). Therefore, it is important to understand the effects of cannabis legalization among EAs.

Adult-use cannabis legalization means a likely increase in exposure to cannabis advertising, which is a mechanism of influencing perceptions and behaviors. Harm perceptions can be shaped by social norms around use, the appeal or aspirational quality of a product, and perceived outcome expectancies from use, all of which can be influenced by advertising and marketing. Understanding what aspects of cannabis marketing and advertising are effective through scientific inquiry supports recommendations for changes to state policies and regulations. In an era of evolving cannabis legalization, there are important implications that result from understanding cannabis advertising effects on perceptions and behaviors, how EAs use cannabis in legal and non-legal environments, and whether cannabis advertising wellness messaging influences perceptions among EAs.

The overall purpose of this dissertation is to map and summarize the scientific literature on cannabis advertising effects on perceptions and behaviors, understand how cannabis use behaviors are associated with legality among EAs, and describe how under-age EAs view stress relief messaging on cannabis advertisements. The overall goal is to inform current and future state policies on cannabis advertising and dispensary regulation and support public health interventions to address EAs' susceptibility to

cannabis use, lowered harm perceptions, and potential for sustained patterns of use into adulthood.

AIM 1: Map and summarize the scientific literature on cannabis advertising effects on perceptions and behaviors.

AIM 2: Describe cannabis use behaviors among EAs in the US and compare use behaviors in states with and without adult-use legal sales as well as among EAs under (18-20 years old) and over (21-25 years old) the legal age to purchase cannabis.

AIM 3: Test the effect of stress relief messaging on cannabis advertising on cannabis-related perceptions and intentions among EAs who are under the legal age to purchase cannabis (18-20 years old).

Organization of Dissertation

This dissertation contains six chapters and includes three manuscripts. In the first chapter, I briefly introduce the topic of cannabis legalization, describe emerging adults as a population, and provide an overview of the study aims. In the second chapter, I provide background information on medical cannabis and adult-use, or recreational, legalization and its effects on use behaviors in the US, drawing from national datasets and previous research. I also provide relevant background information on emerging adults and how life stage is a factor on the effects of legalization. Chapters three, four, and five contain the three manuscripts, which summarize the effects of cannabis advertising, focus on describing cannabis use behaviors and associations with adult-use

legalization among emerging adults, and test the effects of stress relief messaging on cannabis advertisements among underage emerging adults' (18-20 years old) perceptions and viewing patterns. The final chapter provides a synthesis of the findings and discusses recommendations for future research and policy.

CHAPTER TWO: BACKGROUND AND SIGNIFICANCE

Cannabis

Cannabis, also referred to as marijuana, is a broad term used to describe the plant *Cannabis sativa (NIH, 2023)*, which belongs to the Cannabaceae family. Cannabis plants, along with its subspecies of *Cannabis Indica*, contain over 100 different chemical compounds called cannabinoids, of which tetrahydrocannabinol (THC) and cannabidiol (CBD) are most commonly known among them (FDA, 2023; NIH, 2023). THC produces a psychoactive effect, or feeling "high" or even energetic when used, while the use of CBD produces feelings of relaxation and stress relief (Breijyeh et al., 2021; Pearce et al., 2014).

Cannabis has a long history of use by people throughout the world. As early as 2737 BC, there is written record of its use by the Chinese emperor and in 1400 BC and 1000 AD, there were more accounts of use in India and North Africa, respectively (Mosher, 2021). In North America, the Pilgrims grew it for its fibers for clothing and it wasn't until the early 1900s, brought mostly by Mexican immigrants, that cannabis would be used recreationally (Mosher, 2021). Today, cannabis is the most common illicit substance used in the US. In 2021, the number of past year users aged 12 and older totaled 52.5 million people and past month users totaled 36.4 million people (13%) in the US (SAMHSA, 2022).

Modes of administration

Cannabis is used in many ways, such as through smoking, eating, drinking, vaporization (vaping) of oils or concentrated cannabis, and the use of topical ointments and oral tinctures. Most cannabis is consumed by smoking dried herb or flower, either in a cigarette as a "joint", in a water pipe or "bong", or an emptied cigar or "blunt" (Caulkins et al., 2020). Cannabis can be eaten in foods (edibles), beverages (Caulkins et al., 2020), and vaporized, which involves heating cannabis to an aerosol for inhalation, rather than inhaling the smoke from burning the cannabis (Ghosh et al., 2017). Concentrated cannabis can be vaporized or administered by "dabbing," where concentrated cannabis is heated and the aerosol is inhaled (Ghosh et al., 2017). Different modes of administration lead to differences in the length of time until effects are experienced and how long they last for the user (Borodovsky et al., 2016; Klumpers & Thacker, 2019). Smoking or ingesting cannabis vary in the length of time, intensity, and duration of effect (Cloutier et al., 2022). For example, the onset of effects is quicker for those who smoke cannabis compared to ingesting cannabis, although ingestion effects last longer than the "high" from smoking (Cloutier et al., 2022).

Cannabis-related perceptions and behaviors

Cannabis-related harm perceptions have decreased among adolescents and adults (Carliner et al., 2017). Among people aged 12 and over, cannabis is perceived as much less harmful to health compared to using other illicit drugs, drinking alcohol (4-5

drinks per day), smoking a pack or more of cigarettes daily, and inhaling secondhand smoke from tobacco (Chambers et al., 2023; SAMHSA, 2022). EAs believe that using cannabis relieves pain, stress, and anxiety (Malain et al., 2023). Further, compared to EAs who have never used cannabis, EAs who use cannabis hold greater beliefs in the health benefits of use and lowered belief in the potential harms from use (Malain et al., 2023). The extent to which people perceive harm from using substances is an influential factor for future use (SAMHSA, 2022).

Health and social consequences of use

Using cannabis can be accompanied by various health effects, depending on use patterns, such as frequency and intensity of use. Acute and chronic effects may include impaired cognitive development, functioning, and learning, altered motor coordination, inattention, cannabis use disorder (CUD), and exacerbation of schizophrenia symptoms (WHO, 2023). Additional health consequences of use may include lung irritation leading to problem breathing, increased heart rate, adverse child development during and after pregnancy, and negative effects on mental health (NIH, 2021).

There are also reported health benefits of cannabis use. In terms of personal health, people have reported success in using cannabis to treat symptoms of conditions including nausea, sleep inadequacy, lack of appetite, post-traumatic stress disorder, anxiety, epilepsy, and fatigue (Bobitt et al., 2019; Klumpers & Thacker, 2019). Additionally, according to the National Academies of Sciences report on the health

effects of cannabis, there is moderate to substantial evidence in the scientific literature that supports cannabis as a treatment for chronic pain in adults, nausea from chemotherapy, multiple sclerosis, and sleep improvement (National Academies of Sciences & Medicine, 2017).

There are social consequences from using cannabis that can impact health. For people who use cannabis and operate motor vehicles, there is an increased risk of accidents due to altered motor coordination while under the influence of cannabis (WHO, 2023). Cannabis can also affect pregnancy outcomes, as use during pregnancy is associated with negative developmental outcomes for the child (Badowski & Smith, 2020). Further, while the majority of people who are pregnant do not use cannabis during pregnancy, most pregnant people believe that daily or weekly cannabis use is not a risky behavior (Ko et al., 2015). Cannabis use can also affect educational attainment among students, where use is associated with lower academic achievement (Farhat et al., 2011; Jones & Jones, 2019; Jones et al., 2018). Additionally, there is a bi-directional association between using cannabis and mental health issues in the scientific literature (Hu et al., 2023; Mark et al., 2021; Meng et al., 2022; Weinberger et al., 2019) and evidence to suggest that frequent cannabis use among adolescents increases the risk of experiencing psychotic symptoms (Di Forti et al., 2019; Wilson et al., 2019). Early initiation of cannabis use is also associated with polysubstance use and cannabis use dependence later in life (Volkow et al., 2014). Cannabis use disorder (CUD) is another potential negative consequence of continued cannabis use. Signs of CUD may include

increased and continued cannabis use, inability to cease use, continued use that disrupts daily life (e.g., school, work, relationships, etc.), risky use (such as use while operating a moving vehicle), increased use intensity, and withdrawal symptoms from quitting use (CDC, 2023).

Emerging adults (EAs)

EAs are characterized by their stage of life, a transitional time from adolescence into adulthood, which typically occurs between the ages of 18 and 25 (Arnett, 2007; SAMHSA, 2021). These years can be difficult for many people as the transition from adolescence to adulthood is typically defined by less connection to early family life though not yet having a family or career of their own (Arnett, 2007). During emerging adulthood, EAs may leave home, which promotes increased feelings of freedom and autonomy. While for some this is a welcomed transition, for others, this transition can lead to feelings of anxiety and depression (Arnett, 2007).

Emerging adulthood is characterized by five features: exploring one's identity, instability, being focused on the self, feeling in-between or in transition between adolescence and adulthood, and feeling that life is full of possibilities (Arnett, 2005). These features help explain why substance use rates are particularly high in this population (Arnett, 2005). Before settling down for relationships or a career, EAs explore their own identity to understand who they are, which can involve having new experiences, such as experimenting with substances for the first time. Instability for EAs

refers to the many changes they make in their lives: jobs, place of residence, or starting or finishing college. Instability can promote feelings of anxiety and stress and can lead to substance use as a coping mechanism. Instability from changes in friends or social groups can also influence cannabis use. Emerging adulthood is a time to be focused on the self, where there is less connection to family life and less parental control. Family cohesion and parent communication are protective factors for substance use (Cardenas et al., 2022). In addition, people choose friends with similar interests, which means EAs who are curious about using substances will seek friends with similar interests, which encourages substance use (Arnett, 2005). EAs often feel in between adolescence and adulthood, which can be associated with experimentation with substance use. EAs perceive adulthood to be a time of increased responsibility and stability and emerging adulthood as the time before accepting responsibility. Therefore, EAs may desire to have experiences that they would likely not participate in as an adult, as those behaviors are not perceived to be socially acceptable in adulthood. Emerging adulthood is a time when life is full of possibilities and there is a sense of optimism about the future. This optimism may also lead to the inability to see the negative consequences of substance use.

Prevescalation is a concept that refers to the prevention of escalation of substance use (Villanti et al., 2019), which is particularly important during emerging adulthood, as this stage of life is associated with an increase in substance use behaviors. Typical prevention efforts have focused on either preventing initiation of use among

adolescents or cessation of use among adults, which has left a gap in prevention efforts among EAs. The *prevescalation* approach focuses on the time between experimental use and more established use, where interventions can interrupt the transition to increased or sustained use. This concept is important for cannabis research since many adolescents and EAs will initiate cannabis use and without intervention, many will continue to use. Preventing escalation of use, or more frequent use, can be a targeted approach to prevent negative health outcomes from established use.

EAs and cannabis

In addition to being a growing population of cannabis users (Sherburne, 2023), EAs are also the age group with the largest proportion of cannabis users in the US (SAMHSA, 2022; Sherburne, 2023). In 2021, 24.1% of past-month users (over 8 million people) were EAs, 12.2% (26.8 million people) were adults 26 years and older, and 5.8% (1.5 million people) were adolescents 12-17 years old (SAMHSA, 2022). According to the Monitoring the Future (MTF) longitudinal panel study, a survey that tracks adolescents into adulthood to understand substance use behaviors, in 2022, 44% of young adults 19-30 years old used cannabis in the past 12-months, which showed a trend in increasing use over the past 10 years (Sherburne, 2023). Daily cannabis use also increased among this population, reaching the highest percentage recorded at 11% (Sherburne, 2023). Twenty-one percent of young adults 19-30 years old also reported vaping cannabis in the past 12 months, almost doubling since 2017 (Sherburne, 2023). Additionally, EAs

also reported the highest percentage of CUD (14.4%), which is more than triple the proportion of CUD reported among adolescents or adults (SAMHSA, 2022).

US cannabis legalization

The US government uses drug scheduling to classify drugs according to abuse potential and acceptable medical use (DEA, 2023). Schedule V classifies drugs with the lowest abuse potential, while Schedule I groups drugs having the highest potential for abuse and dependence, which includes cannabis (DEA, 2023). Although cannabis is not legal federally, most states have laws and regulations to enable various forms of cannabis legalization.

Legalization of a drug means allowing and potentially regulating its production, distribution, sales, possession, and use (Caulkins et al., 2020) and there are tradeoffs of legalizing cannabis. There are potential consequences of legalization on a community or society, such as increased cannabis use and over-consumption. Although, by choosing not to regulate legalization, a community or society accepts the consequences associated with an illicit market, enforcing laws (Caulkins et al., 2020), and increased arrests (Adinoff & Reiman, 2019). Cannabis legalization contributes to ending the “war on drugs”, a declaration from the Nixon administration that designated cannabis as a Schedule I drug, and addressing racial justice issues (Miron & Partin, 2021). This declaration created inequity among racial/ethnic minority groups in enforcement of cannabis-related offenses (Miron & Partin, 2021).

Even though cannabis use is not federally legal, some US states have implemented regulations related to cannabis production, distribution, use, and sales. Regulations may include the types of cannabis products allowed, concentration limits, purchasing age restrictions, regulations for medical or adult-use cannabis programs, and allowing home cultivation practices, to name a few. In 1996, California became the first state to legalize cannabis for medical use (*California's Cannabis Laws*, 2022). As of April 2023, 38 US states, Washington, DC, and three US territories had laws permitting medical cannabis sales (NCSL, 2023). Sales of medical cannabis occur through dispensaries that provide access to cannabis for those with medical cannabis cards and state-specified approved health conditions. Access to these programs and sales varies, as states and individual cities have imposed limits on dispensary density, locations, and number of licenses or permits (*Cannabis Licenses*, 2022).

Some states are following a trend towards legalizing recreational, or adult-use, cannabis. Many of the barriers to accessing cannabis in illegal or medical-only environments are no longer present with adult-use sales, as those aged 21 years and older with valid state identification can purchase cannabis at legal dispensaries. As of November 2023, 24 US states, Washington, DC, and two US territories allowed sales of adult-use cannabis (NCSL, 2023).

Legal cannabis sales have steadily increased profits for businesses in states with medical and adult-use laws (Dilley et al., 2023) and increased the availability and accessibility of cannabis. By the end of 2027, medical and adult-use combined sales are

projected to reach $53.5 billion dollars, according to one analysis (MJBizDaily, 2023). In Colorado, edible sales increased 332% and sales of cannabis flower, or herb, increased 129% since legal sales began in the state (Hinckley et al., 2022). Cannabis concentrates, used as an oil, were also a popular mode purchased at dispensaries, where sales increased 480% after legal sales began and constituted 32% of cannabis sales in Colorado (Hinckley et al., 2022). Currently, 165.1 million Americans (half of US adults) live in both medical and adult-use legal cannabis environments, with 84.3 million of those people living in adult-use legal states (Buchholz, 2023), which creates a large base of consumers for a growing cannabis industry. Contributing to this growth, four additional US states (Delaware, Minnesota, Ohio, and Virginia) have legalized adult-use sales and will likely begin sales in the near future (NCSL, 2023).

Legalization benefits and consequences

Societal benefits of cannabis legalization are decreasing costs from drug law enforcement and incarceration, a potential lessening of the strength of the illicit cannabis marketplace, and where legal, the ability to govern the safety of cannabis products by way of regulating cannabis amounts and labeling and packaging (Adinoff & Reiman, 2019; Caulkins et al., 2020). Benefits to EAs and adults include the decrease in cannabis-related offenses that lead to arrest and incarceration (Adinoff & Reiman, 2019).

There are also negative consequences of cannabis legalization. Legalization is associated with changing social norms, such as more accepting views and increased support for cannabis use (Carliner et al., 2017) and decreased harm perceptions from use (Rudy et al., 2021; Schuermeyer et al., 2014). Legalization is associated with adverse pregnancy outcomes, CUD, and seeking treatment for problematic cannabis use (Wilson & Rhee, 2022). As more states adopt legalization policies and social norms and perceptions change, adolescent initiation of use and frequency of use is also likely to increase (Perski et al., 2020).

Perhaps the biggest question concerning adult-use cannabis legalization is whether it is associated with changes in cannabis use behavior. Among adolescents, previous studies found little to no association between cannabis legalization and risk perceptions, current use, or frequent use (Brooks-Russell et al., 2019; Coley et al., 2021; Dilley et al., 2019). Many studies used cross-sectional study designs repeated at multiple time points and lacked a comparison group (Brooks-Russell et al., 2019; Dilley et al., 2019). Other studies used legalization law implementation rather than retail cannabis sales as the exposure variable (Coley et al., 2021; Kan et al., 2020), which likely does enable accounting of cannabis marketplace expansion and increased availability and access through cannabis dispensaries (Smart & Pacula, 2019).

There are mechanisms of legalization that affect perceptions and behaviors among adolescents. Exposure to cannabis advertising, greater dispensary density, and proximity to cannabis dispensaries are associated with positive use expectancies and

increased cannabis use and intentions to use (Borodovsky et al., 2017; D'Amico et al., 2015; D'Amico et al., 2018; Hust et al., 2020b). In addition to advertising recall, adolescents who favored particular cannabis brands or owned branded merchandise had increased odds of cannabis use or reporting a cannabis use disorder (Trangenstein et al., 2019, 2021). Further, adult-use legalization is also associated with increased perceived ease of accessing cannabis (Harpin et al., 2018).

Among adults, cannabis legalization is associated with past-month cannabis use, more use of high-potency cannabis products, and cannabis use initiation (Goodwin et al., 2021; Gunadi et al., 2022; Hasin et al., 2021). Similar to the studies with adolescents, these studies used legalization law enactment rather than legal retail sales as the exposure, but they all used comparison states to understand differences by state legalization. Additionally, in states with legal retail cannabis sales, there is greater exposure to cannabis advertising compared to non-legal states among adults (Rup et al., 2020). Advertising exposure is associated with positive cannabis-related attitudes, lowered harm perceptions from use, and increased odds of use (Cohn et al., 2023; Han & Shi, 2023). Adults in legal states also used more high potency cannabis compared to adults in non-legal states (Hasin et al., 2021).

Legalization and emerging adults

Compared to adolescents and adults, there are considerably fewer studies investigating legalization policy effects on EAs. Further complicating the research on

legalization effects is the lack of consistency in state laws (Pacula & Smart, 2017). Laws range from decriminalization of cannabis, allowing CBD products only, to medical or adult-use sales (NCSL, 2023). Additionally, there is heterogeneity within laws, which makes comparisons more difficult (Pacula & Smart, 2017).

Analysis of National Drug Use and Health (NSDUH) data showed that among EAs aged 18-25 years, adult-use cannabis policy enactment was not associated with increased past 30-day (P30D) use or frequent use (used 20 days or more in the past month) or CUD in the past year (Cerdá et al., 2020). These findings could be due to measuring policy enactment and not implementation of retail sales. In contrast, compared to states without adult-use cannabis legalization including retail sales, there were increases in past 30-day use and frequent use among college students living in legal states (Bae & Kerr, 2020). In legal states, 59% of EAs who used cannabis reported obtaining products from adult-use dispensaries (D'Amico et al., 2020) and longitudinally, the proportion of college students who used monthly increased in an adult-use legal state compared to a non-legal state (Barker & Moreno, 2021). Additionally, cannabis-related attitudes and intentions to use did not differ between legal and non-legal states (Barker & Moreno, 2021), potentially due changing social normative beliefs around cannabis that have occurred nationwide (Barker & Moreno, 2021).

Advertising

A usual accompaniment to adult-use legalization is state regulation of cannabis advertising. Advertising is a form of persuasive communication aimed at influencing consumer beliefs or behaviors (*Encyclopedia: Advertising Effects*, 2019), with the ultimate goal of increasing sales. Advertising functions to highlight a product as better than the competition, communicate product information, such as its novelty or function, and persuade potential customer use (*Encyclopedia: Advertising Effects*, 2019).

Measurement of advertising effectiveness can be assessed by considering the immediate effects and overall effectiveness. Effects can be measured through an advertisement's (ad's) ability to evoke emotions (Poels & Dewitte, 2019), promote awareness, increase knowledge, influence attitudes and perceptions, and increase sales (Wright-Isak, 1997). Effectiveness can be viewed as a more long term, or a cumulative measure, where over time there may be an increase in positive perceptions and social norms associated with a product or brand (Wright-Isak, 1997). The way an ad is processed by an individual can be subtle, complex, or both, and understanding the effects and effectiveness offer important insights into overall ad effectiveness (Wright-Isak, 1997).

Advertising and substance use intentions and behaviors

Adult-use legalization has opened a pathway for cannabis industry initiation and expansion (in the case of pre-existing medical cannabis laws) of advertising. The effects

of cannabis advertising can be examined through decades of previous research on alcohol and tobacco advertising effects.

Alcohol and tobacco advertising exposure, oftentimes operationalized through self-reported advertising or brand recall, brand receptivity (owning branded merchandise), or participation in a brand-sponsored event, is associated with susceptibility to use, intention to use, and alcohol and tobacco use behaviors among youth (Dai & Hao, 2016; Finan et al., 2020; Lovato et al., 2003; Margolis et al., 2018; NCI, 2008; Petticrew et al., 2017; Stroup & Branstetter, 2018). A systematic review of longitudinal studies measuring the impact of tobacco advertising on smoking behaviors for non-smokers at baseline found that advertising exposure was positively associated with adolescent tobacco use (Lovato et al., 2003). Among EAs, appealing features of tobacco advertisements, such as price promotion and natural scenery, were associated with interest in using (Moran et al., 2021) and youth exposure to vaping ads in the US, Canada, and England was associated with positive cannabis-related perceptions (Cho et al., 2019).

It is worth noting that there are limitations to measuring advertising exposure. Ad exposure is often measured through participant self-reported recall and with the use of cross-sectional study designs, where results can be subject to recall bias. Another factor is selective attention (Stevens & Bavelier, 2012), where an individual may focus on a particular feature or message for processing, and similarly ignore other features. One example of selective attention is a person who is interested in or curious about

cannabis and therefore, notices cannabis ads more frequently than people who lack interest in cannabis. Conversely, not noticing ads could be the result of a lack of interest in cannabis or cannabis use, which is also selective attention. Ads may be present in the environment and potentially viewed, but no recall is reported. Previous research results have shown that substance users reported higher frequencies of ad exposure compared to non-users (Cho et al., 2019), but these findings do not reveal whether exposure affected use or if people who use cannabis notice ads more. Further research that can identify causal relationships through longitudinal or experimental study designs between ad exposure and perceptions and behaviors would provide more robust conclusions on the effects of ad exposure and greatly benefit this field of research.

There are similarities and differences between laws and regulations and the use of tobacco, alcohol, and cannabis. Both tobacco and alcohol are similar to cannabis in that the industries are regulated federally and/or by states, there are age requirements for purchase, and all three constitute the most commonly used substances in the US (SAMHSA, 2021). A main difference for cannabis is the that the industry is relatively new, there is little consistency in regulations between states, and due to the marketing of cannabis as a product beneficial for health and wellness (Liu et al., 2020; McQuoid et al., 2023), advertisement messaging for cannabis likely differs from alcohol and tobacco. Therefore, there is a need for more research on the effects of cannabis advertising.

Theory and Conceptual Model

The conceptual model below (Figure 1) illustrates how aspects of adult-use cannabis legalization affect EAs' intention to use and behaviors using constructs from the Theory of Planned Behavior (TPB) and the Social Cognitive Theory (SCT) (Ajzen, 1991; Glanz, 2015).

The TPB has been used to predict different health behaviors, such as substance use. In the conceptual model in Figure 2-1, TPB is used to illustrate how beliefs and attitudes (*perceived risks/harm*, *perceived benefits,* and *attitudes*) and perceived behavioral control, or *self-efficacy* are associated with *intention to use* cannabis (Glanz, 2015). The TPB highlights *intention* to perform the behavior as a major influence on actual behavior change (Glanz, 2015), or *cannabis use.* It is important to mention that there are criticisms to the TPB and its dedicated pathway from beliefs and attitudes to *intention* (Sniehotta et al., 2014). While intentions to engage in a behavior can indeed lead to action, individuals may also intend to behave in one manner and then simply not perform the behavior (Sniehotta et al., 2014). This could be due to changes in circumstances such as relocation from a cannabis legal to a non-legal state, where the environment changes and perceived access and availability of cannabis are influenced. In addition, there may be other variables that are influential in behavior change than just attitudes and beliefs, therefore, the TPB remains a useful theory, but it's necessary to add constructs to predict associations that provide additional utility.

The SCT has been used in health research to understand how personal cognitive, behavioral, and environmental factors all influence one another to effect behavior change, referred to as reciprocal determinism (Bandura, 1986; Glanz, 2015). In the model in Figure 2-1, personal cognitive factors, or *perceptions, environmental factors* represented as *social norms* and *access and availability,* and *behavioral factors,* or *intentions* and *use,* all work to influence one another.

Personal cognitive factors, or *perceptions,* include the constructs of p*erceived risks or harm*, *perceived benefits*, *attitudes, outcome expectancies*, and *self-efficacy*. There are different types of risk or harm related to obtaining or using cannabis, which can be psychological, physical, legal, social, or health-related (*Types of Harm*, 2023) and risks or harm are often considered alongside *perceived benefits,* or the gains one may receive from performing a behavior. Harms and benefits are not always weighed equally, as societies and people have accepted higher risks and lower benefits from behaviors such as smoking and alcohol use (Fischhoff et al., 1978). *Outcome expectancies* are the perceived rewards or consequences of performing a behavior and some examples include the anticipation of feeling "high" or an expectation of social belonging from using cannabis because of perceived peer use. Additionally, an individual might believe in less adverse health effects as a result of using cannabis products from a legal dispensary. Another personal cognitive factor is represented as *self-efficacy*; the confidence or belief in one's ability to perform a behavior (Glanz, 2015). *Self-efficacy* can be based on successful previous experiences, such as smoking cannabis, a behavior that

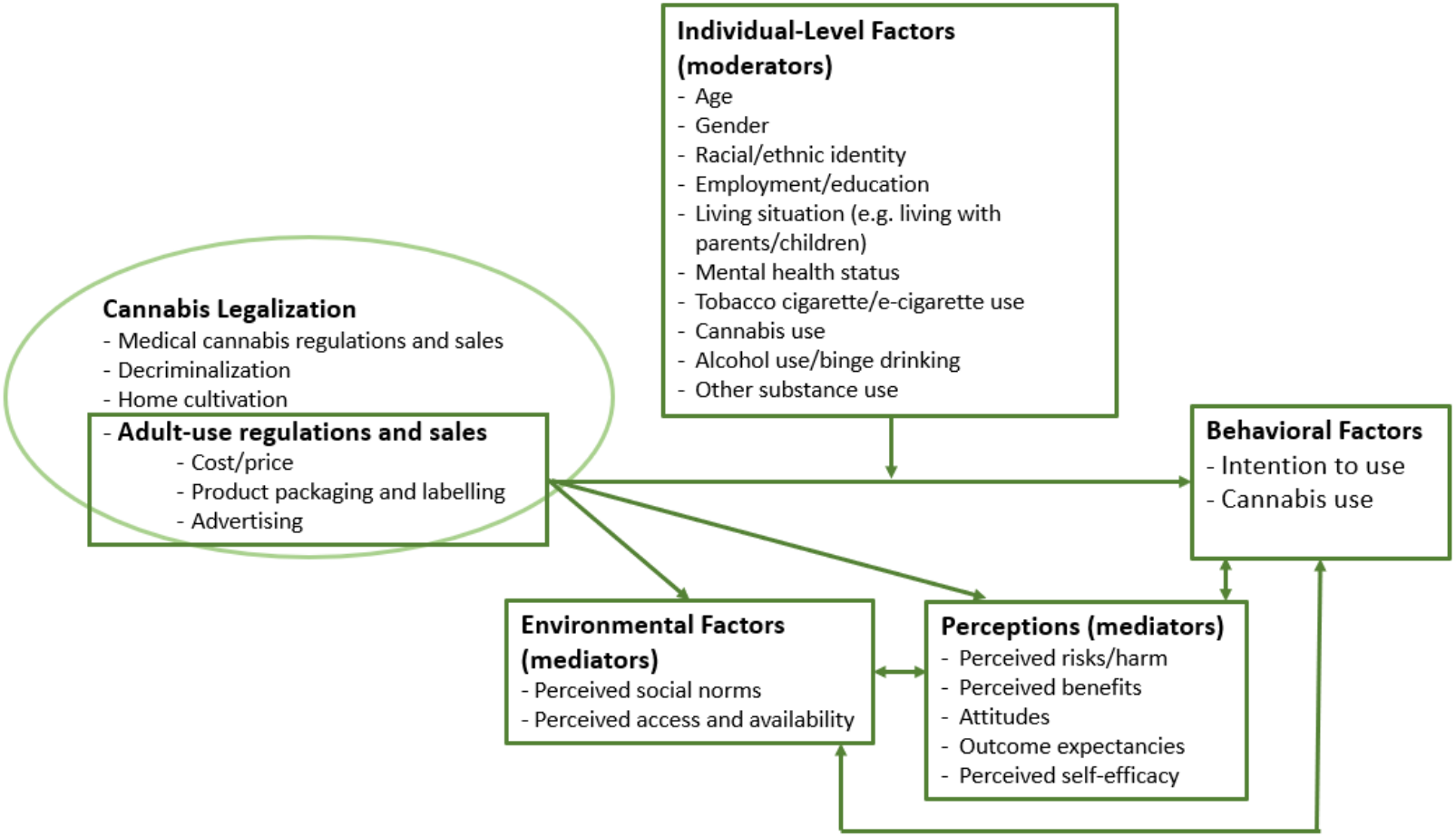
is also supported by a person's social group, which may boost self-efficacy related to future use.

Environmental factors are represented in the model as *perceived social norms* and *perceived access and availability*. *Social norms* constitutes both descriptive and injunctive norms (Rimal & Lapinski, 2015). Descriptive norms are an individual's motivation to engage in a behavior that is perceived to be what most people are doing (Rimal & Lapinski, 2015), such as using vapes for cannabis use, where increased exposure to advertising promoting vaping products influences perceived social norms around use. Injunctive norms are behaviors individuals engage in to gain group affiliation (Cialdini & Goldstein, 2004; Rimal & Lapinski, 2015). An example is the association between increased use of cannabis concentrates among adolescents and the perception of increased peers' use (D'Amico & McCarthy, 2006). Descriptive norms are important factors that influence behavior, but without the presence of injunctive norms, the behavior is less likely to occur (Rimal & Lapinski, 2015), which is due to the need for people to have a sense of belonging. Injunctive norms are especially important for EAs, as group affiliation becomes more important due to the transition out of adolescence and away from the influence of parents (Napper et al., 2016). Perceptions of access and availability are also important influential factors, as beliefs that cannabis is easy to access is associated with increased cannabis use (Wadsworth et al., 2022).

The moderators in the model are individual-level factors that affect the association between legalization and cannabis use outcomes among EAs. Age, gender,

income, and racial/ethnic identity are associated with cannabis use (Bae & Kerr, 2020; Jeffers et al., 2021; W. C. Kerr et al., 2018; Miller et al., 2017). Cigarette smoking and e-cigarette use behaviors are associated with cannabis use (Lanza et al., 2021), as well as alcohol use (Ito et al., 2021; Kerr et al., 2017; Looby et al., 2021), which may be used alongside or as a substitute to cannabis (Subbaraman, 2016). Last, mental health status is associated with cannabis use, as cannabis has been used to alleviate symptoms associated with mental health issues or used as a coping mechanism (Moitra et al., 2021; Pedrelli et al., 2015), such as for stress or anxiety (Mitchell et al., 2007).

FIGURE 2- 1. CONCEPTUAL MODEL ILLUSTRATING CANNABIS LEGALIZATION POLICY EFFECTS ON CANNABIS-RELATED BEHAVIORS



CHAPTER THREE: MANUSCRIPT 1: A SCOPING REVIEW OF THE EFFECTS OF CANNABIS ADVERTISING EXPOSURE ON PERCEPTIONS AND BEHAVIORS

ABSTRACT

Background: The effects from cannabis advertising are not well understood and may differ from alcohol and tobacco advertising due to social norms around cannabis use and cannabis industry claims of health and wellness.

Objective: To map the scientific literature on cannabis advertising and its associations with perceptions and behaviors among various population groups in the US.

Eligibility Criteria: Studies were eligible for inclusion if they were in English, examined cannabis industry advertisement (ad) features or as a whole, examined advertising on billboards, the internet, print ads, storefront displays, etc., studies where the outcomes were perceptions, attitudes, behaviors, intention to use, and/or use expectancies, and studies on cannabis ad policies and/or regulations. Any study design that fit the eligibility criteria was included, which included experiments, observational, qualitative, or systematic reviews.

Sources of Evidence: I used three relevant databases to search the scientific literature: PubMed (NCBI), PsycINFO (EBSCO), and Business Source Complete (EBSCO).

Charting the evidence: Systematic review software was used to chart relevant information from the primary sources found, which included author, date, ad type(s), measures, and important findings.

Results: After title/abstract screening and full text review, 17 articles that fit eligibility criteria were charted and summarized. Results were categorized into two themes based on the outcomes of interest: cannabis-related perceptions, attitudes, and beliefs and

cannabis-related intentions and behaviors. Most studies were cross-sectional study designs and used participant recall to measure exposure to advertising. The majority of studies found that that cannabis advertising was associated with positive cannabis-related perceptions, attitudes, and use behaviors among adolescent, emerging adult, and adult populations.

Conclusions and relevance: Most of the studies found effects from advertising exposure, although the majority of studies used cross-sectional study designs and participant recall to measure advertising exposure. Using experimental study designs to test the effects of appealing features on ads among different age groups might offer further insight into advertising effectiveness. Policy recommendations include limiting youth-appealing features on cannabis ads, which includes positive use expectancies messaging, and cannabis advertising on the internet that is not contained within cannabis industry business websites.

INTRODUCTION

Cannabis advertising is widespread in the US due to an increasing number of states allowing legal retail sales. Advertising is persuasive mode of communication that can influence consumer perceptions and behaviors and ultimately, increases sales (*Encyclopedia: Advertising Effects*, 2019; Wells, 1997). Cannabis advertising ranges from the use of outdoor billboards, magazine advertisements (ads), radio, social media posts, to cannabis industry webpages. Levels of exposure to advertising vary throughout the country, depending on state cannabis legality, internet availability and accessibility, and advertising restrictions (Schauer, 2021). As cannabis advertising is relatively new compared to alcohol and tobacco advertising, the effects are less well understood.

Advertising is a persuasive marketing technique used to increase the odds of purchasing a service or a product (*Encyclopedia: Advertising Effects*, 2019) and can be measured by examining effects and effectiveness (Wright-Isak, 1997). Effects are generally immediate and can be measured though an individual's emotional response to the ad (Poels & Dewitte, 2019), increase in knowledge, attitudes and perceptions, awareness, and sales, to name a few (Wright-Isak, 1997). Effectiveness is a cumulative measure, where changes can be measured over time, such as an increase in positive perceptions of the product or social norms (Wright-Isak, 1997). Advertising might be effective through the use of appealing or salient features on an ad, promoting a unique or novel quality of a product, eliciting an emotional response from the viewer which increases positive perceptions and promotes use (Poels & Dewitte, 2019), or using

multiple modes of advertising (billboards and radio ads) to increase exposure which promotes familiarity and future recall (Wells, 1997).

Exposure to alcohol and tobacco advertising has been linked to increased tobacco- and alcohol-related perceptions and behaviors (Finan et al., 2020; Lovato et al., 2011; NCI, 2008; Petticrew et al., 2017). In a recent review of alcohol and tobacco advertising content and effects from advertising exposure, greater tobacco and alcohol retailer density and advertising exposure were associated with increased tobacco use, brand loyalty, susceptibility to use, and experimenting with smoking among adolescents (Weitzman & Lee, 2020). Similarly, alcohol retailer density and exposure to alcohol ads were correlated with lower age of initiation of alcohol, increased alcohol acquisition, brand loyalty, lifetime use, and heavy use (Finan et al., 2020; Weitzman & Lee, 2020). Further, tobacco and alcohol ad appeal were associated with positive attitudes towards smoking, susceptibility to smoking, and greater alcohol-related positive perceptions (Weitzman & Lee, 2020). While there is strong evidence supporting the association between alcohol and tobacco advertising exposure and effects, the effects from cannabis advertising exposure are not as well understood.

The presence of cannabis advertising is a relatively new phenomenon. Unlike current tobacco and alcohol marketing, the cannabis industry has focused on promoting products as beneficial to overall health and wellness (Liu et al., 2020; Luc et al., 2020; McQuoid et al., 2023). Advertising is generally an effective method of attracting attention and increasing sales, but due to additional health claims on cannabis ads and

cannabis-related perceptions and use expectancies, the effects of cannabis advertising exposure may differ from those of alcohol and tobacco. In order to understand the scientific literature on cannabis advertising effects, this study employed a scoping review of the literature using approaches outlined by Arksey & O'Malley (2005) and Levac et al. (2010). The purpose is to map the scientific literature on cannabis advertising and to summarize the state of the science on the effects (cannabis-related attitudes, perceptions, and behaviors) of advertising exposure and how effects are being measured. The results will inform future research on advertising effects and current and future cannabis advertising policies and regulations.

METHODS

Eligibility Criteria

Inclusion and exclusion criteria are detailed in Table 3.1.

Table 3- 1. Scoping review inclusion and exclusion criteria

Inclusion Criteria	Written in English
	Included all populations (i.e., ages, race/ethnicities)
	Examined specific features of ads (i.e., colors, text, photos, etc.)
	Examined ad location placement and/or density
	Examined effects from exposure to various ad modes (i.e., social media posts, internet ads/banners, outdoor billboards, magazine or print ads, tv, or radio)
	Investigated effects from exposure to other features of ads (such as brands, products, retail or other cannabis-related industry businesses [i.e., home delivery], or cultivation businesses)

	Used outcomes such as perceptions, attitudes, behaviors, intention to use, and/or use expectancies
	Examined cannabis ad policies/regulation effects that used similar outcomes
	Used experimental, observational, qualitative, or systematic review designs
Exclusion Criteria	Used ads promoting substances other than cannabis
	Used content analysis study designs due to the lack of effects on perceptions, attitudes, and behaviors

Information sources and search strategy

With the help of a University of Nevada, Reno (UNR) librarian, I searched the literature using three databases: PubMed (NCBI), PsycINFO (EBSCO), and Business Source Complete (EBSCO). These databases were deemed the most relevant for searching the advertising and marketing literature as well as effects on public health. Search strings that included Medical Subject Headings (MeSH) and their equivalents in PsycINFO and Business Source complete were developed. Additional search terms used were “cannabis” OR “marijuana” AND "advertising" OR "marketing" OR “promot” OR “sale” OR “selling” AND “attitudes” OR “perceptions” OR “behaviors” OR “intention” OR “expectancies.” Use of these terms were limited to the title and abstracts fields of records in the three databases to increase the likelihood of retrieving relevant studies and each database’s English language filter was used to exclude those published in other languages. Search terms were edited appropriately for each database. Searches were conducted from April-May, 2023.

Study selection process and data management

Once the search strategy was configured for the specific database, resulting articles were uploaded into Covidence online software, which helps authors collaborate on systematic and other review protocols (*Covidence Systematic Review Software*, 2023). Covidence's built-in de-duplication tool identified and removed any duplicate records before beginning the screening process. Articles were then sent for title and abstract screening, which were reviewed manually. For the full text screening, I reviewed all articles according to the eligibility criteria and necessary outcomes and exposure measures.

Data Charting

Data charting is the process of synthesizing the relevant data from the primary sources (Arksey & O'Malley, 2005). Using Covidence, the following information was extracted and charted for this review (summarized in Table 3.2):

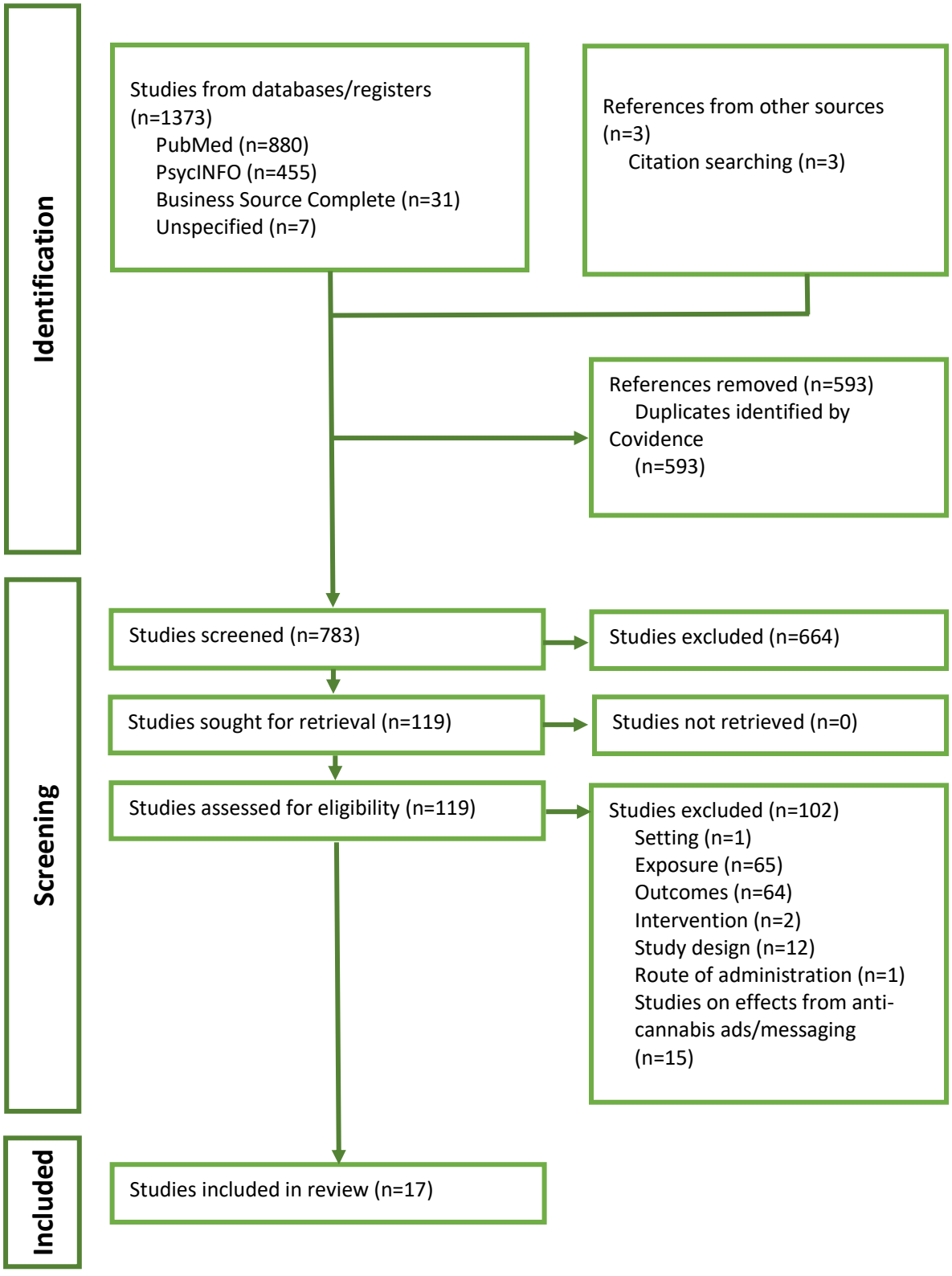
- Primary author and year
- Title
- Country
- Study purpose/aim(s)
- Study design
- Population, number of participants
- Cannabis ad type (billboard, social media, storefront display, etc.)
- Cannabis ad element studied (whole ad, ad feature, other)
- Measures
- Important/relevant results

RESULTS

Characteristics of the sample

Database searches were conducted in April-May 2023 and produced 1,373 articles, with three articles found by citation searching. A total of 593 duplicates were removed. Of the 783 articles reviewed through title and abstract screening, 664 articles were excluded. A full text review on 119 articles followed, where 102 articles were excluded during this process due to multiple reasons, which are included in the PRISMA diagram (Figure 3.1). This process resulted in 17 articles for data charting and reporting (Table 3-2).

FIGURE 3- 1. PRISMA DIAGRAM OF DATABASE SEARCH FOR STUDIES ASSESSING EFFECTS OF CANNABIS ADVERTISING



Themes

The search resulted in 11 cross-sectional, four longitudinal, one online experiment, and one qualitative study. The studies' outcomes of interest were grouped into two themes: 1) *Cannabis-related perceptions, attitudes, and beliefs* and 2) *Cannabis-related intentions and behaviors*. The results were organized by study design. The majority of the studies in this review measured advertising exposure through participant recall, whether in the past 30-days (P30D), past 3-months (P3M), or longer.

Cannabis-related perceptions, attitudes, and beliefs

Eight studies included perceptions, attitudes, or beliefs as outcomes, including five cross sectional, one longitudinal, one experimental, and one qualitative study design. Along with other behavioral effects that are discussed in the next section, the longitudinal study measured cannabis ad exposure and use expectancies at all seven waves of data collection to understand the associations between exposure and the outcomes over time (D'Amico et al., 2018). The authors found that P3M self-reported exposure to billboard, magazine, or other cannabis ads was associated with positive cannabis-related use expectancies among adolescents (D'Amico et al., 2018). In the experimental study, exposure to sex-themed social media ads among college students resulted in positive cannabis use expectancies (Willoughby et al., 2023). Further, exposure to sex-themed ads lowered sexual risk expectations, such that participants

believed that using cannabis resulted in more pleasurable sexual experiences while disbelieving that there were sexual risks associated with using cannabis.

Five studies investigated effects of advertising exposure on cannabis-related perceptions, attitudes, and beliefs using cross-sectional study designs. Adolescents in middle school who recalled ads in front of dispensaries had lowered harm perceptions from using cannabis, an association not detected among high school students (Firth et al., 2022). Tveleneva et al. (2022) found that among EAs, there was no association between P3M recall of online cannabis advertising (through email, text messages, websites, and social media) and cannabis use risk perceptions or positive attitudes about cannabis. Cohn et al. (2023) found that reporting a greater number of ad sources (outdoor ads, social media posts, newspaper or magazine ads, and internet ads) was associated with positive cannabis-related attitudes among adults 18 years and older. Further, although statistically significant, recalling print ads was associated with less positive attitudes compared to recalling billboards and internet ads and recalling outdoor ads and social media posts was statistically significantly associated with lowered harm perceptions (Cohn et al., 2023).

Two of the cross-sectional studies focused on data sources with dispensary location information rather than relying on self-reported participant recall. Shih et al. (2019) used medical dispensary location data to investigate the effects of storefront signage indicating cannabis near EAs' homes; living near signage was associated with positive cannabis use expectancies primarily among EAs under 21, the legal age to

purchase cannabis. Similarly, Han & Shi (2023) found that adults who lived near dispensaries with storefront advertising had lowered odds of perceived harm from using cannabis.

One qualitative study used focus groups to understand the effects of tobacco and cannabis ads on perceptions. EAs 17-21 years old discussed their beliefs that cannabis marketing and advertising did not influence their intentions to use. Study participants were also opposed to public health anti-cannabis use messaging, desiring to make their own decisions about whether or not to use cannabis without outside influences (Liu et al., 2020).

Cannabis-related intentions and behaviors

As legalization continues to increase access and availability of cannabis in the US, it is important to understand the effects of advertising on behaviors. Out of 14 studies examining advertising and cannabis use intentions and behaviors, four of the studies assessed ad exposure effects on behavioral outcomes using longitudinal study designs. In the study by D'Amico et al. (2018), adolescent ad recall, such as billboards, magazines, social media, and dispensary storefront displays was associated with greater intentions to use cannabis and more frequent use at each wave of data collection. In another study by the same author, adolescents who recalled seeing cannabis ads had greater intentions to use cannabis the following year compared with youth who did not remember seeing ads (D'Amico et al., 2015). The authors of this study also reversed the

exposure and outcome in analyses and found that P30D cannabis use was associated with three times increased odds of noticing ads the following year (D'Amico et al., 2015). Among EAs, P3M recall of ads (by way of billboards, storefront signs, internet, radio, or television) predicted greater odds of P30D cannabis vaping two years later (DiGuiseppi et al., 2023). Similarly, among college students, any recall of electronic nicotine delivery system (ENDS) ads predicted use of ENDS with cannabis, increased cannabis use, and ever use of ENDS with cannabis one year later (Kreitzberg et al., 2019).

There were ten studies that examined effects of advertising on behavior using cross-sectional study designs. Adolescents, EAs, and adults who recalled cannabis advertising (billboard, magazine, internet, social media posts, etc.) had greater odds of cannabis use, increased intention to use, more multi-modal use (herb/flower and edibles or concentrates and herb/flower for example), and higher odds of CUD (Cohn et al., 2023; Fiala et al., 2020; Firth et al., 2022; Hust et al., 2020b; Rup et al., 2020; Trangenstein et al., 2022; Trangenstein et al., 2021; Tveleneva et al., 2022; Whitehill et al., 2020) compared to those who did not recall ads. Cohn et al. (2023) found an association between recalling a greater number of sources of marketing and increased odds of P30D cannabis use. Cohn et al. (2023) also found that while billboard and social media marketing exposure were associated with cannabis use, print ads and internet marketing were not associated with use. In Han & Shi's (2023) study investigating effects of storefront signage, the authors found that a higher density of dispensaries

with signs indicating cannabis sales and dispensaries with signs indicating health benefits of cannabis use were associated with greater odds of P30D cannabis use and greater odds of adults' use of both medical and adult-use cannabis (Han & Shi, 2023).

An exception to these findings is that one study found that adolescents who recalled ads on the social media platform Instagram had lowered odds of frequent cannabis use; however, the same study found that participants who recalled billboard ads had seven times increased odds of frequent use compared to those who never saw ads (Trangenstein et al., 2021).

DISCUSSION

Exposure to cannabis advertising was associated with positive cannabis-related perceptions, attitudes, and use behaviors throughout the lifespan. Among the articles in this study, there were four longitudinal studies and one experimental study that found that ad exposure was associated with positive use expectancies, increased intentions to use, and increased cannabis use. There were 11 cross-sectional studies that found associations between cannabis ad exposure and lowered harm perceptions, positive cannabis-related attitudes, positive use expectancies, increased intentions to use, greater odds of use, more use of additional modes, and use of medical and recreational cannabis. Most of the studies used cross-sectional study designs and relied on participant self-reported recall to measure advertising exposure.

The majority of the studies in this review, regardless of study design, used participant self-reported recall (either past 30-day, 3-month, or lifetime) to measure advertising exposure. This measurement has the potential to bias estimates as results are subject to recall bias and limited accuracy on recall due to the length of time between exposure and reporting (Gregan-Paxton, 1997). For example, participants in some of the studies were asked about specific advertising exposure, such as on the internet or on billboards. If participants were exposed to billboard ads, but were asked about cannabis ads on the internet, the participant might respond that they had not seen any internet advertising. Likely, the potential influential effects of the ad exposure would have persisted and been reflected in their reported perceptions or behaviors even though they reported no ad exposure. These limitations partially explain why Tveleneva et al. (2022) found no association between past 3-month recall of internet advertising and perceptions among EAs and Trangenstein et al. (2021) found that greater exposure to internet promotions on Instagram was associated with lowered odds of frequent use. The study findings from Trangenstein et al. (2021) are similar to another study where the authors found no association between Instagram use and cannabis use among emerging adults (Bergman et al., 2018). Both studies suggest that Instagram is not used as frequently by cannabis users as non-users and that cannabis' federally illegal status may prevent users from posting cannabis-related content. Additionally, in a content analysis of cannabis posts on Instagram, only 9% of posts were advertisements that were likely industry-generated (Cavazos-Rehg et al., 2016).

There are limitations on interpretations of cross-sectional study findings in the context of advertising exposure as associations between variables are identified but findings cannot explain the association any further. For example, individuals who are interested in using cannabis or have more lenient attitudes towards use may be more attuned to advertising and notice them more than someone who lacks interest in cannabis. Individuals who lack interest in cannabis or hold negative perceptions of use might fail to notice the ads they are "exposed" to in their daily routine. Additionally, in one of the studies by D'Amico et al. (2015), there were two time points of data collection where exposure to the ads (exposure) and cannabis use (outcome) were measured. The authors analyzed exposure and outcome (cannabis advertising and use) and then reversed the exposure and the outcome for additional analysis. Reversing the exposure and outcome potentially leads to understanding associations but not necessarily causation.

Recognizing the limitations of these studies, important effects were found that warrant further discussion. Internet advertising exposure, through social media posts, industry websites, or cannabis banner ads, was found to be effective at influencing perceptions and behaviors in most of the studies. Internet advertising is not just contained within states with legal cannabis retail sales and access is limited only by internet availability. Therefore, these are important effects to understand further, as problematic use, such as increased intensity and frequency of use as well as CUD, in

adolescence can lead to more established patterned use in emerging adulthood and adulthood (Villanti et al., 2019).

Some studies found that increased exposure through multiple types of advertising (billboard, magazines, internet, etc.) had a greater effect on positive perceptions and use behaviors than fewer sources. This finding is related to a theoretical concept that underlies advertising effectiveness (Wright-Isak, 1997), where over time, repeated exposure to brands or products may increase the product's acceptability and use. This action creates familiarity with and trust of the product and increases perceptions of social acceptability for use.

Study findings helped to highlight gaps in research on advertising effects. An investigation of the effects from wellness messaging or promotion of health benefits, which are features commonly included in cannabis advertising (Hoeper et al., 2022), would be a useful endeavor. Ad messaging that includes communication about health, whether reduced risk from using edibles compared to smoking or benefits to health overall, such as for stress or pain relief, are potentially highly influential messages and warrant further investigation. Understanding the effects on perceptions and behaviors of various cannabis marketing product claims is vital for addressing potentially misleading messaging by initiating public health activities that promote and distribute accurate health information. Previous research on features of alcohol advertising resulted in the creation and application of a youth-appealing index (Padon, Rimal, et al., 2018), which was then applied to tobacco ads (Padon, Lochbuehler, et al., 2018) and

cannabis edibles packaging (Tan et al., 2022). Cannabis advertising likely includes youth-appealing content and further study could apply this index to the various modes of cannabis advertising.

Research using additional study designs and measures could add scientific support to the effects of cannabis advertising. Experimental studies could test exposure to specific features of ads, messaging claims, or design elements that are appealing among various age groups, as appeal likely differs by age. Experimental studies using eye tracking may offer additional insight into effects from advertising exposure. Computer mounted eye tracking devices could be used to measure eye movements and fixations on areas of interest on cannabis ads in order to understand where fixations occur and what features attract the most attention. Additionally, through the use of portable head-mounted devices, such as eye glasses, eye tracking technology could track participants' eye movements and fixations as they walk through neighborhoods where cannabis ads are located.

There were a few limitations to this study. The search was focused on studies that investigated cannabis industry advertising, which did not include effects from user-generated online content or social media influencers, who also "advertise" or promote products. It was my intent to limit studies to cannabis industry content to offer recommendations for policy and regulations around cannabis advertising. Another limitation is publication bias, which potentially limits the conclusions on effects from advertising exposure. Publication bias refers to the lowered likelihood of studies with

null results to be published in the scientific literature and therefore, be excluded from this study. Despite increasing interest in publishing null results, there could be an unknown number of studies with null results that are out there and could not be included in this study.

Conclusions

Though effects from advertising exposure were found, the majority of studies used cross-sectional study designs and participant recall to measure advertising exposure. To understand cannabis advertising effects, experimental study designs may be better suited to test specific features of ads or designs that are appealing to specific age groups. Eye tracking technology could also be beneficial to understanding effects, as attention to ads or features can be measured, analyzed, and associated with perceptions and attitudes. Similar to those from alcohol and tobacco advertising exposure studies, policy recommendations include limiting advertising in locations where there is youth present, positive use expectancies messaging, and internet cannabis advertising that is not contained within cannabis industry business websites.

Table 3- 2. Summary of studies that examine cannabis advertising effects (n=17)

First Author (year)	Research Design	Purpose/Aim(s)	Sample	Cannabis Ad Measures	Outcome(s) of interest
Cohn (2023)	Cross-sectional	Effects of cannabis marketing exposure on use perceptions and behavior	n=5284 adults	P30D* recall	- Attitudes - Harm perceptions
D'Amico (2015)	Cohort	Exposure to medical cannabis advertising and associations with intentions to use and use in the next 6 months	n=8214 6th-8th grade students	P3M** recall	- Intentions to use - Ad recall
D'Amico (2018)	Cohort	Exposure to medical cannabis advertising and adolescent marijuana use, intentions to use, and positive use expectancies	n=4946 EAs	P3M recall	- Cannabis use - Intentions to use - Positive use expectancies - Negative consequences from use
DiGuiseppi (2023)	Cohort	Exposure to specialty e-cigarette retailers (i.e., vape shops) and cannabis ads and use of e-cigarettes to vape nicotine and/or cannabis	n=2123 EAs	P3M recall	- Cannabis use
Fiala (2020)	Cross-sectional	Determine whether advertising exposure was associated with ad exposure	n=14,852 8th graders, n=11,895 11th graders	P30D recall	- Cannabis use
Firth (2022)	Cross-sectional	To understand how storefront signs were associated with cannabis use and harm perceptions	n=24,154 8th and 11th grade students	P30D ad recall	- Cannabis use - Harm perceptions

Han (2023)	Cross-sectional	Examined the associations of adult-use cannabis availability and storefront signage with cannabis use outcomes	n=3385 adults	Presence of dispensary storefront signs	- Harm perceptions - Cannabis use - Dual purpose use (medical + recreational)
Hust (2020)	Cross-sectional	Examined the association between perceived cannabis retailer distance and intentions to use	N=343, adolescents 13-17 years old	Frequently of viewing ads	- Intentions to use
Kreitzberg (2019)	Cohort	To understand the association between exposure to electronic nicotine delivery system (ENDS) advertising and use of ENDS with cannabis	n=3720 college students	P30D recall of ENDS ads	- Cannabis use
Liu (2020)	Qualitative	To understand perceptions of online tobacco and marijuana advertising and on social media, ad appeal and how messaging influences behaviors	N=24 EAs 17-24 years old	Interview questions: cannabis ad exposure and perceptions	- Attitudes - Perceptions of ad appeal
Rup (2020)	Cross-sectional	Examined cannabis ad exposure and brand awareness across three jurisdictions; Canada, US medical legal states, and US medical non-legal states	N=26,710 (Legal states: n=7,292; Illegal states: n=9,578) 16-65 years old	P12M*** recall	- Cannabis use
Shih (2019)	Cross-sectional	To understand the association between medial cannabis availability and storefront signage and cannabis use frequency and other risk behaviors	n=1887 EAs	Density of dispensary storefront signage	- Cannabis use - Perceptions, beliefs, attitudes - Use expectancies

Trangenstein (2021)	Cross-sectional	Evaluated association of cannabis marketing receptivity and cannabis use, CUD, frequent use, and high intensity use among lifetime cannabis users	n=172 adolescents 15-19 years old	P30D recall	- Cannabis use
Trangenstein (2022)	Cross-sectional	Latent class analysis that examined cannabis marketing exposure, internet use, and cannabis use	n=471 adolescents and EAs 15-19 years old	Frequency of viewing ads	- Cannabis use - Attitudes - Receptivity to promotional items
Tveleneva (2022)	Cross-sectional	Evaluated relationships between cannabis advertising and risk perceptions, attitudes, and behaviors	n=523 EAs 18-26 years old	P3M recall	- Intention to use - Risk perceptions - Attitudes - Use expectancies
Whitehill (2020)	Cross-sectional	Examined associations between cannabis marketing exposure and cannabis use	N=469 adolescents and EAs 15-19 years old	Any exposure to social media ads and P30D of billboards/ newspapers/ magazines	- Cannabis use
Willoughby (2023)	Experiment	Examined exposure to sexualized cannabis ads to understand association with sex expectancies	n=498 EAs, college students	Exposure to sexualized cannabis ads	- Risk perceptions - Use expectancies

CHAPTER FOUR: MANUSCRIPT 2: CANNABIS USE AMONG EMERGING ADULTS IN US STATES WITH AND WITHOUT LEGAL CANNABIS SALES USING THE INTERNATIONAL CANNABIS POLICY STUDY (ICPS) WAVE 4 2021 DATA

ABSTRACT

Background/Purpose: Cannabis legalization laws have contributed to changes in the US social and policy landscape. In 2021, the largest proportion of past 30-day cannabis use was among emerging adults (EAs) aged 18-25 years compared to people younger and older (SAMHSA, 2022), with many EAs legally able to purchase cannabis in states with legal retail sales. The purpose of this study was to understand the association between cannabis use patterns (frequency of use, modes, source, and source legality) of emerging adults who were under (18-20 years old) and over (21-25 years old) the legal age to purchase cannabis and state legality.

Methods: Using 2021 International Cannabis Policy Study wave 4 data from the US (n=3,467), EAs' patterns of use (use frequency, mode, number of modes, cannabis source, and source legality) were described. Among the sample of past 12-month (P12M) EA users, logistic and linear regression were used to understand the associations between cannabis use behaviors and state legality by age group (under and over the legal age of cannabis purchase).

Results: Among the sample of EAs 18-25 years old, 33% used cannabis in the P12M and half reported never use. Compared to EAs in non-legal states, EAs in legal states had higher odds of being a weekly user (aOR 1.46; 95% CI: 1.05, 2.04). While there were no differences in use patterns among under-age EAs, over-age EAs in legal states had greater odds of being a P12M user (aOR 1.41; 95% CI: 1.03, 1.92) or a multi-modal user (aOR 1.34; 95% CI: 1.04, 1.72) than over-age EAs in non-legal states. Both under- and

over-age EAs in legal states had higher odds of obtaining cannabis from a dispensary than in non-legal states (aOR 2.14; 95% CI: 1.31, 3.48 and aOR 6.02; 95% CI: 4.40, 8.24, respectively). Additionally, over-age EAs in legal states had lower odds of obtaining cannabis from a dealer than over-age EAs in non-legal states (aOR 0.3; 95% CI: 0.24, 0.44). Under-age EAs in legal states who used cannabis concentrates used them on almost 34 more days in the P12M than under-age EAs in non-legal states (95% CI: 10.33, 56.21). Overall, EAs in legal states reported obtaining almost 25% more legally sourced cannabis in the P12M than EAs in non-legal states (95% CI: 19.32, 29.94).

Conclusions: Among over-age EAs living in legal states, there were more P12M users, more multi-modal use, less use of dealers and more use of dispensaries to obtain cannabis, and more legally sourced cannabis than in non-legal states. Although there were no differences in use frequency among under-age EAs in legal vs. non-legal states, under-age EAs who used cannabis and lived in legal states accessed dispensaries more, used more legally-sourced cannabis, and used cannabis concentrates more frequently than EAs in non-legal states. Under-age EAs' use of concentrates is concerning, due to the health effects from use of products with higher potency levels, and highlights the gap in understanding the mechanisms driving increased use, whether social norms around use acceptance or increased access in legal environments. It is unclear how under-age EAs are obtaining legal cannabis and using dispensaries in legal states and warrants further investigation.

INTRODUCTION

In 2021, a greater proportion of emerging adults (EAs) 18-25 years old reported using cannabis in the past 12 months (35.4% or 11.8 million people) than adolescents 12-17 years old (10.5% or 2.7 million people) or adults 26 years and older (17.2% or 37.9 million people) in the US (SAMHSA, 2022). EAs also reported the highest percentage of cannabis use disorder (CUD) (13.5%). About 15% of EAs perceived harm from smoking cannabis once or twice a week, compared to 35% of adolescents and 27% of adults' harm perceptions of cannabis use (SAMHSA, 2022). Recreational, or adult-use, cannabis legalization is associated with EAs' cannabis use behaviors. Compared to states without adult-use cannabis legalization, there are increases in past 30-day (P30D) cannabis use among EAs living in legal states (Bae & Kerr, 2020; Barker & Moreno, 2021; D. C. R. Kerr et al., 2018). As more states are poised to legalize adult-use cannabis for legal retail sales, it is important to understand cannabis use behaviors and if adult-use sales influence use patterns among EAs.

EAs are in a transitional stage of life, where experimentation with substance use, such as cannabis, is more common and can be part of normal developmental processes relative to other life stages (Arnett, 2000). Many EAs have moved away from parents or guardians, no longer under their rules or protection, but have not fully accepted more adult responsibility by settling into careers or family life (Arnett, 2000). While substance use experimentation is more socially acceptable during this life stage, there is concern

that casual substance use among EAs may escalate to more frequent, established use (Arnett, 2005).

Cannabis legalization is implemented through a variety of state-level policies and regulations in the US (NCSL, 2023) such as decriminalization, medical use where access is limited to those with certain medical conditions, and recreational, or adult-use of cannabis, where access is limited only by age. As of November 2023, 24 states, two territories, and DC allowed retail sales of adult-use cannabis (NCSL, 2023). States with operating dispensaries as of November 2023 that sold adult-use cannabis included Alaska, Arizona, California, Colorado, Connecticut, DC, Illinois, Maine, Maryland, Massachusetts, Michigan, Missouri, Montana, Nevada, New Jersey, New Mexico, New York, Oregon, Rhode Island, Vermont, and Washington. States that have passed regulations for adult-use legalization but have not begun sales include Delaware, Minnesota, and Virginia. Adult-use legalization that includes retail sales has allowed many states to open dispensaries, increasing product promotion, sales, and cannabis use (Manthey et al., 2023).

Legal cannabis sales and age may be influential factors in cannabis use patterns. There is evidence that legalization is associated with cannabis use frequency; states with adult-use cannabis sales had less never users and more past-year, monthly, weekly, and daily users compared to states without adult-use sales (Goodman et al., 2020). Among EAs, there is evidence that living in states with legal sales is associated with the use of cannabis modes alternative to smoking, such as edibles or vaporizers, compared to

living in non-legal states (Romm et al., 2021). Age may also be a factor as greater dispensary density has been associated with increased use among adolescents and EAs who are not of legal age to purchase cannabis products (Manthey et al., 2023). Cannabis advertising exposure among older adolescents has also been associated with increased use and intention to use cannabis (D'Amico et al., 2018; Hust et al., 2020a).

EAs are in a unique phase in life, where cannabis use experimentation is more common than in other life stages. Increased advertising and access to cannabis may influence cannabis use behaviors (D'Amico et al., 2018; DiGuiseppi et al., 2023) not just among EAs legally able to purchase cannabis but also among EAs under the legal age of purchase (Manthey et al., 2023) through social pressure (D'Amico & McCarthy, 2006) and increased access to cannabis products through the legal marketplace. Therefore, the purpose of this study was to describe the association between EAs' cannabis use behaviors (frequency of use, mode type used, use of multiple modes, cannabis source, and source legality) and state legality (states with legal adult-use sales vs. states with no legal adult-use sales) among EAs who were under (18-20 years old) and over (21-25 years old) the legal age of purchase. I hypothesized that living in a state with legal adult-use cannabis sales would be associated with more frequent cannabis use among all EAs. Among only P12M users, legalization would be associated with higher mode use frequency, greater multi-model use, less cannabis obtained from dealers and family/friends and more from dispensaries, and a greater proportion of cannabis obtained from legal sources.

METHODS

Dataset

Data were drawn from the US sample from Wave 4 (2021) International Cannabis Policy Study (ICPS). The objective of the ICPS is to understand the impacts of cannabis legalization on prevalence and patterns of use, the retail sales environment, cannabis-related behaviors and perceptions, and regulatory cannabis policy effectiveness. ICPS data is collected annually with participants aged 16-65 years living in Canada and the US, and starting in 2021, Australia and New Zealand. Wave 4 data was collected from September to November 2021 (Corsetti, 2022). For the wave 4 dataset, 30,081 US respondents were sampled and a sub-sample of 3,467 US EAs were included in the current analysis.

ICPS participants were recruited using non-probability sampling through the *Nielsen Consumer Insights Global Panel* (*Nielsen Insights*, 2023) and were compensated for their time according to their panel's structure for incentives. Participants provided consent before completing the survey, which was an online survey in English. Median time for survey completion was 22 minutes, with longer survey times reported for past 12-month users compared to never users due to the increased number of questions. The study protocol has been reviewed by The University of Nevada, Reno Office of Research Integrity and received ethics approval (Protocol #2026518-1).

Measures

Exposure: State legal sales status. There were 11 states with legal adult-use cannabis sales as of September 2021: Alaska, Arizona, California, Colorado, Illinois, Maine, Massachusetts, Michigan, Nevada, Oregon, and Washington. The rest of the states prohibited adult-use cannabis sales.

Frequency of cannabis use. The frequency of cannabis use variable was derived from three survey questions that assessed lifetime, recent, and current use: 1) lifetime cannabis use, where participants were asked: “Have you ever tried marijuana?” (response options: “yes” or “no”); 2) recent use, where participants were asked: “When was the last time you used marijuana?” (response options: “More than 12 months ago”; “More than 3 months ago but less than 12 months ago”; “More than 30 days ago, but less than 3 months ago”; and “Within the past 30 days”); and, 3) current use, where lifetime users were asked: “How often do you use marijuana?” (response options: “less than once per month”; “one or more times per month”; one or more times per week”; and “every day or almost every day”). The derived cannabis use frequency variable contained mutually exclusive categories of use, which included: “never user”; “used more than 12 months ago”; “past 12-month user”; “monthly user”; “weekly user”; and “daily/almost daily user.” I used the cannabis use frequency derived variable to analyze and compare use frequency and P12M use overall, across state legal sales status, and by age group.

Cannabis use mode. Participants who used cannabis in the P12M were asked what modes of cannabis they used, with responses that included: “dried herb (smoked, vaped, including pre-rolled joints)”; “cannabis oils or liquids taken orally (e.g., drops, capsules or sprays)”; “cannabis oils or liquids for vaping”; “edibles/foods”; “drinks (e.g., marijuana cola, tea or coffee)”; “concentrates (e.g., wax, shatter, budder)”; “hash or kief”; “tinctures (concentrated amount ingested orally or taken under the tongue)”; “topical ointments (e.g., skin lotions or bath products)”; and “other (please specify).” I used the derived binary response variables for each mode, which included: 1: “yes, in the past 12 months” and 0: “no, not in the past 12 months or don’t know.” For 105 participants in the sample of P12M users, none of the modes were selected from the list provided; therefore, they were excluded from analyses of mode. For analysis, I report the four top modes, combining remaining modes into their own category. For analyses with multi-modal use, I used the mode variable as categories of 1, 2, 3, 4, 5, and 6+ modes.

Cannabis source. Participants who used cannabis in the P12M were asked, “In the past 12 months, have you gotten any type of marijuana from the following sources?” Multiple responses were possible and included: “I made or grew my own”; “From a family member or friend”; “From a dealer (in person)”; “Internet delivery service or mail order (delivered to me)”; “From a store, co-operative or dispensary”; “Other (please specify without providing any identifiable information)”; and “I haven’t obtained marijuana from any source in the past 12 months.”

Cannabis source legality. P12M cannabis users were asked, “Overall, how much of the marijuana you used in the past 12 months was purchased from legal/authorized sources?” Participants entered a number from 0-100 to represent the percentage of legal cannabis that they used in the P12M.

Covariates. Sociodemographic characteristics included age group (18-20 years old; 21-25 years old), sex (“female”; “male”), race (White; Black; Other small groups [Asian, American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, multiple ethnicities; and “other”]), Hispanic ethnicity (“yes”; “no”; “don’t know”; and “refuse to answer”). Other covariates included income adequacy and mental health problems, as they are associated with cannabis use (Jeffers et al., 2021; Walsh et al., 2017). For income adequacy, participants were asked: “Thinking about your family’s income, how difficult or easy is it to make ends meet?” Response options were collapsed into categories: very difficult/difficult; neither easy nor difficult; very easy/easy; don’t know; refuse to answer. Mental health was assessed by asking participants: “Have you experienced any of the following mental health problems in the past 12 months? Select all that apply.” Response options included: “anxiety (including phobia, obsessive-compulsive disorder or a panic disorder)”; “depression (including dysthymia)”; “post-traumatic stress disorder (PTSD) or traumatic event (e.g., abuse or loss)”; “bipolar disorder, mania, or borderline personality disorder, psychosis (e.g., paranoia, disorganized thinking, hearing voices that others can’t hear) or Dissociative Identity Disorder”; “Schizophrenia”; “alcohol or other drug use”; “eating disorder”;

"ADD/ADHD"; "autism spectrum disorder (including Asperger's)"; "cannabis use disorder"; "no, I have not experienced these mental health problems in the past 12 months"; and "don't know." Mental health responses were collapsed into categories: experienced at least one mental health issue in the past 12 months; experienced no mental health issues in the past 12 months, don't know, and refuse to answer.

Other substance use variables were included in the regression models because they are associated with cannabis use (Kowitt et al., 2019; Wardell et al., 2021). I used two variables to assess past 30-day (P30D) cigarette, e-cigarette, and alcohol use. To assess ever use, participants were asked: "have you ever used any of the following drugs?" where responses included "tobacco cigarettes"; "e-cigarettes/vaped nicotine"; and "alcohol." For any positive responses, participants were asked about recent use with the question: "When was the last time you used [insert drug]" with response options that included: "more than 12 months ago"; between 3 to 12 months ago"; "between 1 and 3 months ago"; "within the last month"; "within the last week"; "don't know"; and "refuse to answer." Responses were collapsed into any vs. no P30D use. I also included past 12 month binge drinking as a covariate, which is associated with cannabis use (Jones & Jones, 2019), by including two variables that assessed drinking frequency and binge drinking. Drinking frequency was assessed by asking participants: "During the past 12 months, how often did you usually have any kind of beverage containing alcohol?" where response options included: "every day or nearly every day"; "three or four times a week"; "once or twice a week"; "one to three times a month";

"seven to 11 times in the last 12 months"; "three to six times in the last 12 months"; "twice in the last 12 months"; "once in the last 12 months"; "never in the last 12 months"; "don't know"; and "refuse to answer." Binge drinking was assessed by asking P12M alcohol users: "How often in the past 12 months, have you had [males=5/females=4/intersex=4-5] or more drinks on one occasion?" with response options that included: "never"; "less than once a month"; "once a month"; "2 to 3 times a month"; "once a week"; "more than once a week"; "don't know"; "refuse to answer." Positive binge drinking was assessed as any past 12-month binge drinking.

Statistical analysis

A total of 59,391 people completed the 2021 survey and the final analytic sample consisted of 52,938 people after removing respondents for dishonesty (at the end of the survey, participants were asked: "were you able to provide 'honest' answers about your marijuana use during the survey"), poor data quality, sex identity of "intersex" (due to insufficient numbers for weighting), speeding through the survey, multiple attempts, and unstated US state or territory. A sub-sample of 3,467 EAs from the US dataset were analyzed in the current study.

The variables did not contain any missing data, as questions were forced responses and participants could select "don't know" or "refuse to answer" for most questions. When cell counts for these variables were often too small for analyses, they were set to missing. "Don't know" and "refuse to answer" responses were set to missing

for the following variables: Hispanic ethnicity (n=78), cigarette use (n=20), e-cigarette use (n=17), and alcohol use (n=19). “Refuse to answer” was set to missing for the following variables (“don’t know” responses were included in analyses): mental health status (n=107), income adequacy (n=105), and binge drinking (n=93).

Post-stratification sample weights were constructed by the ICPS team and based on US Census data. More detailed information on weighting can be found in the technical report (Corsetti, 2022). Data used in analyses were weighted.

Descriptive statistics were used to describe the study sample of all EAs and P12M-using EAs. I used adjusted multinomial logistic regressions to model the odds of the different use frequency categories versus being a never user and adjusted linear regression to compare the differences in number of days used for each use mode (dried herb, vaping, edibles, etc.), cannabis source prevalence (family/friend, dealer, etc.), and for percentage of legally sourced cannabis used in the P12M. I used adjusted ordinal logistic regression, which satisfied the proportional odds assumption (Agresti, 2007), to model the odds of using 1-6 modes of cannabis. All models were adjusted for the following covariates: age group, sex, race, Hispanic ethnicity, income adequacy, mental health status, cigarette use, e-cigarette use, alcohol use, and binge drinking. SAS v. 9.4 was used for all statistical analyses (SAS, 2015).

RESULTS

Characteristics of the sample

Table 4.1 describes the overall sample of EAs, along with description of the sample stratified by under- and over-age groups in states with legal and no legal sales. Overall, 57.6% (95% CI: 55.1, 60.1) were female, 63.6% (95% CI: 61.4, 65.9) were between 21-25 years old, 59% (95% CI: 57.0, 61.7) identified as White, 71% (95% CI: 69.0, 73.6) were of non-Hispanic ethnicity, and 62% (95% CI: 59.8, 64.6) reported a mental health problem in the previous 12 months. While 50% (95% CI: 47.9, 52.7) of EAs had never used cannabis, 14% (95% CI: 12.7, 16.0) used cannabis daily or almost daily.

There were some differences in sociodemographic characteristics and substance use in legal and non-legal states. There were more under- and over-age people who identified as Black in non-legal states than in legal states (under-age: 28.2% [95% CI: 24.0, 32.4] vs. 16.2% [95% CI: 11.6, 20.9] and over-age: 26.2% [95% CI: 24.0, 32.4] vs. 16.2% [95% CI: 11.6, 20.9]). More under-age EAs identified as Hispanic in legal states (34.5%; 95% CI: 28.1, 40.9) compared to non-legal states (22.6%; 95% CI: 18.9, 26.3). Among under-age EAs, there were more P30D cigarette users (3.6%; 95% CI: 2.3, 4.9) and e-cigarette users (12.4%; 95% CI: 9.8, 15.0) in non-legal states than in legal states (cigarettes: 1.4% [95% CI: 0.6, 2.2] and e-cigarettes: 6.8% [95% CI: 4.6, 8.9]).

Table 4.2 describes the sub-sample of EAs who were P12M cannabis users, which constituted 33% (95% CI: 30.9, 35.2) of the total sample of EAs, by sociodemographic characteristics, substance use behaviors, the number of days used in the P12M for each mode of cannabis, number of modes used, cannabis source, and percentage of legally

sourced cannabis. On average, people who used dried herb used it on 121 days (95% CI: 112.1, 130.0), people who used vaporizers vaped on 63 days (95% CI: 55.9, 69.3), people who consumed edibles took them on 31 days (95% CI: 26.7, 44.3) and people who used concentrates used them on 39 days (95% CI: 32.7, 44.3) out of the past 365 days. Twenty percent (95% CI: 17.2, 23.6) of P12M EA cannabis users used one mode of administration, 17% (95% CI: 14.4, 20.3) used two modes, 18% (95% CI: 14.9, 21.7) used three modes, 16% (95% CI: 13.1, 18.7) used four modes, 10% (95% CI: 7.8, 11.9) used five modes, and 18% (95% CI: 14.8, 21.6) used six or more modes in the P12M. About 50% (95% CI: 45.7, 53.5) of P12M users obtained cannabis from family/friends, 41% (95% CI: 36.7, 44.3) from dealers, and 43% (95% CI: 39.5, 47.1) from a dispensary. EAs who used in the P12M reported obtaining most of their cannabis legally, reporting 68% (95% CI: 65.4, 70.8) from legal sources.

There were some differences among the P12M user group by state legality. There were more over-age EAs who identified as Black in non-legal (28.0%; 95% CI: 22.5, 33.6) than in legal states (15.5%; 95% CI: 10.4, 20.7). There were also more under-age e-cigarette users in non-legal (29.5%; 95% CI: 22.4, 36.5) than legal states (15.8%; 95% CI: 9.4, 22.3). For the cannabis use behaviors, more under-age EAs who used any other mode used on more days in legal (59.0%; 95% CI: 41.4, 76.7) than non-legal states (28.5%; 95% CI: 17.7, 39.3). While more over-age EAs in legal states sourced cannabis from dispensaries (68.7%; 95% CI: 61.5, 71.8) than in non-legal states (30.4%; 95% CI: 25.2, 35.5), more under-age EAs in non-legal states used a dealer to obtain cannabis

(52.4%: 95% CI: 46.4, 58.3) than in legal states (25.1%; 95% CI: 18.5, 31.7). The last difference was among over-age EAs, where they reported a higher percentage of legally sourced cannabis in legal states (81.4%; 95% CI: 78.1, 84.7) compared to non-legal states (56.1%; 95% CI: 51.0, 61.1).

Table 4.3 shows the percentage of P12M use by sociodemographic characteristics and cannabis use, allowing a comparison of use within each sociodemographic and behavior category. Among all females, 35% (95% CI: 32.4, 37.2) were P12M users; among all males, 31% (95% CI: 26.6, 34.5) were P12M users. There were more P12M users who were 21-25 years old than 18-20 years old (36%, 95% CI: 33.4, 39.1 vs. 24.1%, 95% CI: 24.1, 30.6). There were also significantly more cigarette, e-cigarette, and alcohol users who were P12M cannabis users than EAs who did not use those substances. Of EAs who reported a P12M mental health issue, 37% (95% CI: 34.5, 40.1) used cannabis in the P12M; only 26% (95% CI: 21.8, 30.3) of EAs who reported no mental health issue used cannabis in the P12M.

Cannabis use frequency among all EAs

Compared to living in a non-legal state, EAs living in legal states had 1.46 times increased odds (95% CI: 1.05, 2.04) of being a weekly user compared to being never user. There were no associations found between use frequency and state legal sales status among under-age EAs. Compared to over-age EAs living in non-legal states, over-

age EAs in legal states had 1.41 times increased odds (95% CI: 1.03, 1.92) of being a past 12-month user compared to never user.

Cannabis use mode and multi-modal use among P12M users

State legality was not associated with a difference in the number of days all EAs used dried herb, vapes, or edibles; however, under-age EAs who used concentrates used them on 33 more days (95% CI: 10.3, 56.2) in legal states compared to under-age EAs in non-legal states. Further, under-age EAs in legal states who used any of the other modes (e.g., drinks, hash or kief, tinctures, and topical ointments) used on 35 more days (95% CI: 14.8, 55.9) than under-age EAs in non-legal states (Table 4.5).

EAs in legal states had increased odds of using multiple modes compared to EAs in non-legal states (aOR: 1.26, 95% CI: 1.05, 1.56) (Table 4.4). While there was no difference in multi-modal use among under-age EAs, over-age EAs living in legal states had 1.34 times increased odds of multi-modal use (95% CI: 1.04, 1.72) compared to over-age EAs in non-legal states.

Cannabis source and source legality among P12M users

State legality was associated with most of the sources of cannabis obtained by EAs (Table 4.4). Under-age EAs in legal states had over 2 times greater odds of obtaining cannabis from a dispensary (aOR: 2.14; 95% CI: 1.31, 3.48) and over 6 times greater odds of growing the cannabis themselves (aOR: 6.58; 95% CI: 2.02, 21.39) compared to

under-age EAs in non-legal states. Over-age EAs in legal states had lower odds of obtaining cannabis from family or friends (aOR: 0.74, 95% CI: 0.56, 0.98) or from a dealer (aOR: 0.32, 95% CI: 0.24, 0.44) compared to over-age EAs in non-legal states. On the other hand, compared to over-age EAs in non-legal states, those in legal states had 6 times greater odds of obtaining cannabis from a dispensary (aOR: 6.02; 95% CI: 4.40, 8.24), 2 times greater odds of growing cannabis themselves (aOR: 2.01; 95% CI: 1.24, 3.27), and 1.8 times greater odds of ordering cannabis from the internet (aOR: 1.80; 95% CI: 1.21, 2.67). There was also an association between state legality and the amount of legally sourced cannabis reported by EAs. Under-age EAs in legal states reported obtaining 22.5% more cannabis (95% CI: 10.5, 34.4) from legal sources compared to under-age EAs in non-legal states and over-age EAs reported obtaining 25.6% more legal cannabis (95% CI: 19.7, 31.5) in legal states compared to non-legal states.

DISCUSSION

Legal cannabis sales were associated with multiple use behaviors among all EAs, under-age EAs, and over-age EAs. Overall, compared to EAs living in non-legal states, more EAs living in legal states used cannabis more than 12 months ago and weekly compared to never using. While there were no differences in use frequency categories among under-age EAs, more over-age EAs in legal states were P12M users compared to over-age EAs in non-legal states. Previous research has shown similar associations

among people 16-65 years old, where legalized states have less never users and more P12M, monthly, weekly, and daily users compared to non-legal states (Goodman et al., 2020). The findings of the current study suggest that more EAs tried cannabis in legal vs. non-legal states, a finding that is supported by previous research on EAs in a non-legal state (Bolts et al., 2023), where 70% reported the reason for not using cannabis was based on legality.

Although mode use frequency did not differ by state legality, use of concentrated cannabis among under-age EAs living in legal states was an exception: under-age EAs who used concentrates used on more days in the P12M in legal states than in non-legal states. This finding was similar to previous research where use of concentrates was more common in legal vs. non-legal states among EAs 21-24 years old compared to older age groups (Spindle et al., 2019; Ueno et al., 2021). Interest in concentrates is also high, as internet searches for concentrates, or more specifically "dabbing," have increased (Meacham et al., 2018) and were significantly higher in states with adult-use legalization (Zhang et al., 2016), suggesting increased interest and potentially increased use of concentrates in legal states. Younger EAs may be more inclined to use cannabis concentrates; previous research found that in a state with legal medical cannabis, 72% of adolescents who used cannabis also used concentrates (Meier et al., 2019). Younger EAs may be particularly susceptible to social pressure (D'Amico & McCarthy, 2006) and with the increase in product availability through the legal marketplace, these may be among the driving mechanisms for increased concentrates

use among under-age EAs. Adolescent use of concentrates is of particular concern, as high potency products increases risks of mental health effects and greater severity of symptoms (Wilson et al., 2019) and is associated with increased cannabis use dependence (Meier, 2017).

Legal cannabis sales have not only increased access to cannabis but to a variety of different modes of use as results showed there were more over-age EAs who used multiple cannabis modes in legal states than non-legal states. Although smoking cannabis is the most common mode used by EAs who use cannabis (Ueno et al., 2021), EAs living in legal states are more likely to use modes other than smoking compared to those living in non-legal states (Romm et al., 2021). The current study suggests that access to the legal cannabis marketplace increases the use of multiple products among cannabis users. Vaping and using edibles have gained popularity as well as the use of multiple modes among youth (Hammond et al., 2020; Peters et al., 2018) and younger adults are more likely to use modes such as edibles, vaporizers or vape pens, and concentrated cannabis compared to older adults (Ueno et al., 2021). The novelty of many cannabis modes is an attribute that is generally appealing to youth (Ueno et al., 2021) and is associated with lowered risk perceptions from use (Plurphanswat et al., 2020). Trends in use of new modes or those alternative to smoking may continue to increase, especially as the cannabis industry will likely evolve and produce new modes for cannabis use to attract new users.

Living in legal states was associated with increases in source legality; both under- and over-age EAs reported a greater proportion of cannabis obtained from legal sources in legal vs. non-legal states, but there were differences in where EAs obtained cannabis by state legal sales status. Among over-age EAs in legal states, there were decreased odds of obtaining cannabis from family, friends, or a dealer, but increased odds of using the internet compared to over-age EAs in non-legal states. Use of the internet to obtain cannabis is more likely to occur in legal states, as many dispensaries have options for internet sales and delivery (Weedmaps, 2023). Among both under- and over-age EAs, there were greater odds of obtaining cannabis from a dispensary, growing it themselves, and obtaining cannabis from legal sources in legal vs. non-legal states. It is worth investigating how under-age EAs access dispensaries, as age verification is required upon entry. It is possible that over-age friends or family purchase for them, they bypass age checks through dispensary non-compliance or have false identification, or they possess a medical cannabis card, where age requirements are often lower than for adult-use laws. Another possibility is the utilization of non-licensed, or illegal, dispensaries, which are often indistinguishable from legal dispensaries (Nicholas et al., 2021) and packaging and labeling of products often mimics legal products.

This study is subject to limitations. The ICPS used non-probability sampling methods, which may not necessarily generalize to the US emerging adult population. When data were weighted by legal state, sex, education, region, and smoking status groups and compared to the US population, there were fewer participants with less

education and Hispanic ethnicity and poorer general health was reported. The ICPS survey used participant self-reported recall of modes and source legality, all of which are subject to recall bias. However, to minimize confusion concerning mode, the survey included multiple examples of different product names or types. Another limitation is that although legalization policies differ by state, it is possible for dispensary access to extend its reach to potential customers located out of state (Manthey et al., 2023). This is particularly true for non-legal states that neighbor legal states.

Conclusions

Legalization that includes adult-use retail sales was associated with more P12M users, more multi-modal use, use of fewer dealers and more dispensaries, and more legally sourced cannabis among over-age EAs. Under-age EAs' use frequency was no different in legal and non-legal statues, but they reported more dispensary use, more cannabis sourced legally, and used more cannabis concentrates than under-age EAs in non-legal states. Under-age use of concentrated cannabis is particularly concerning since there are health risks associated with high potency products (Wilson et al., 2019). Under-age EAs also report more dispensary use in legal vs. non-legal states. Increased public health messaging and education on the risks may facilitate less concentrates use among under-age EAs. It is unclear how under-age EAs are obtaining legal cannabis and using dispensaries in legal states. Possible explanations are use of the illicit cannabis

marketplace, the perception that products are legal, and increased access to legal dispensaries, which are all avenues for future investigation.

Table 4- 1. Unweighted sample sizes and weighted proportion (%) and confidence intervals (CI) for sociodemographic, behavioral, and cannabis use characteristics from the International Cannabis Policy Study (ICPS Wave 4 (2021), by state legal sales status and age group (n=3,467)

	Overall (n=3,467)		**Legal Sales States** (n=1,690)		**Non-legal Sales States** (n=1,777)	
			18-20 years old (n=588)	21-25 years old (n=1,102)	18-20 years old (n=659)	21-25 years old (n=1,118)
	n	**% 95% CI**	**% 95% CI**	**% 95% CI**	**% 95% CI**	**% 95% CI**
SOCIODEMOGRAPHIC CHARACTERISTICS						
Sex						
Female	2615	57.6 (55.1, 60.1)	62.9 (56.1, 69.7)	50.3 (45.4, 55.3)	66.9 (62.2, 71.5)	56.1 (52.2, 60.0)
Male	852	42.5 (40.0, 44.9)	37.1 (30.3, 43.9)	49.7 (44.8, 54.7)	33.1 (28.5, 37.8)	43.92 (40.1, 47.8)
Age group						
18-20 years old	1247	36.4 (34.1, 38.6)	35.8 (32.2, 39.5)	---	36.9 (34.2, 39.6)	---
21-25 years old	2220	63.6 (61.4, 65.9)	---	64.2 (60.5, 67.8)	---	63.1 (60.5, 65.8)
Race						
White	2163	59.4 (57.0, 61.7)	62.4 (56.3, 68.4)	64.1 (59.4, 68.9)	52.4 (47.9, 56.8)	57.5 (53.8, 61.3)
Black	592	20.2 (18.4, 22.0)	16.2 (11.6, 20.9)	10.5 (8.1, 12.9)	28.2 (24.0, 32.4)	26.6 (23.2, 30.0)
Other small groups*	712	20.4 (18.4, 22.5)	21.4 (16.3, 26.5)	25.3 (20.8, 29.9)	19.4 (15.9, 23.2)	15.9 (12.9, 18.9)
Hispanic Ethnicity						
Yes	802	25.9 (23.7, 28.2)	34.5 (28.1, 40.9)	28.2 (23.4, 33.0)	22.6 (18.9, 26.3)	21.3 (18.2, 24.5)
No	2587	71.3 (69.0, 73.6)	62.7 (56.3, 69.1)	68.0 (63.1, 73.0)	74.2 (70.3, 78.0)	77.2 (74.0, 80.4)
Don't know	58	2.0 (1.2, 208)	2.4 (1.1, 3.7)	2.4 (0.3, 4.4)	3.0 (1.4, 4.6)	0.9 (0.3, 1.6)
Refuse to answer	20	0.7 (0.3, 1.2)	0.4 (0.0, 1.1)	1.4 (0.1, 2.7)	0.3 (0.0, 0.6)	0.6 (0.0, 0.1)
Income Adequacy**						
Very difficult/ difficult	847	22.9 (20.9, 24.8)	17.4 (12.9, 22.0)	23.4 (19.2, 27.7)	26.2 (22.2, 30.1)	23.4 (20.5, 26.3)
Neither easy nor difficult	1250	35.5 (33.2, 37.8)	39.3 (33.0, 45.6)	35.3 (30.7, 39.9)	33.6 (29.5, 37.8)	34.8 (31.2, 38.4)
Very easy/easy	1007	29.8 (27.6, 32.0)	27.1 (21.6, 32.6)	30.4 (25.9, 34.9)	24.7 (21.1, 28.4)	33.7 (30.1, 37.3)
Don't know	258	7.9 (6.7, 9.2)	10.4 (7.3, 13.5)	5.6 (3.3, 7.9)	12.0 (8.8, 15.2)	6.5 (4.8, 8.1)

Refuse to answer	105	3.9 (2.8, 4.9)	5.8 (3.3, 8.4)	5.3 (2.6, 8.0)	3.5 (1.8, 5.1)	1.7 (0.8, 2.6)
MENTAL HEALTH STATUS						
Mental health issue (past 12-months)						
Yes	2214	62.2 (59.8, 64.6)	55.7 (49.5, 62.0)	61.9 (57.1, 66.7)	62.4 (58.1, 66.7)	59.5 (55.7, 63.2)
No	861	27.3 (25.1, 29.5)	29.6 (23.6, 35.6)	25.9 (21.6, 30.2)	24.2 (20.4, 27.9)	29.2 (25.7, 32.8)
Don't know	285	9.3 (7.9, 10.7)	11.4 (7.5, 15.3)	8.6 (5.7, 11.4)	11.2 (8.3, 14.2)	7.7 (5.7, 9.8)
Refuse to answer	107	3.3 (2.5, 4.1)	3.3 (1.5, 5.0)	3.7 (1.7, 5.6)	2.2 (1.0, 3.4)	3.6 (2.3, 4.9)
SUBSTANCE USE BEHAVIORS						
Cigarette use (past 30-day)						
Yes	267	6.0 (4.9, 7.1)	1.4 (0.6, 2.2)	7.2 (4.7, 9.7)	3.6 (2.3, 4.9)	8.7 (6.5, 10.9)
No	3180	93.5 (92.4, 94.6)	98.5 (97.7, 99.4)	92.4 (89.9, 94.9)	96.0 (94.6, 97.3)	90.5 (88.2, 92.8)
Don’t know	18	0.4 (0.2, 0.7)	0.1 (0.0, 0.2)	0.4 (0.0, 0.8)	0.4 (0.0, 0.8)	0.7 (0.2, 1.3)
Refuse to answer	2	0.1 (0.0, 0.2)	0.0 (0.0, 0.0)	0.0 (0.0, 0.1)	0.0 (0.0, 0.0)	0.1 (0.0, 0.4)
E-cigarette use (past 30-day)						
Yes	416	10.5 (9.1, 11.9)	6.8 (4.6, 8.9)	11.3 (8.4, 14.3)	12.4 (9.8, 15.0)	10.6 (8.0, 13.1)
No	3034	89.0 (87.6, 90.4)	93.1 (90.9, 95.3)	88.1 (85.1, 91.1)	86.8 (84.0, 89.5)	89.0 (86.4, 91.6)
Don’t know	13	0.4 (0.1, 0.6)	0.1 (0.0, 0.4)	0.3 (0.0, 0.7)	0.7 (0.0, 1.5)	0.3 (0.0, 0.7)
Refuse to answer	4	0.1 (0.0, 0.3)	0.0 (0.0, 0.0)	0.3 (0.0, 0.7)	0.1 (0.0, 0.4)	0.1 (0.0, 0.4)
Alcohol use (past 30-day)						
Yes	882	21.4 (19.6, 23.3)	14.4 (10.5, 18.2)	25.3 (21.3, 29.4)	15.7 (12.7, 18.7)	24.9 (21.7, 28.0)
No	2566	78.1 (76.2, 80.0)	85.5 (81.7, 89.3)	74.1 (70.0, 78.2)	83.5 (80.4, 86.5)	74.9 (71.7, 78.0)
Don’t know	14	0.3 (0.1, 0.4)	0.1 (0.0, 0.3)	0.3 (0.0, 0.6)	0.5 (0.0, 1.1)	0.1 (0.0, 0.3)
Refuse to answer	5	0.2 (0.0, 0.4)	0.0 (0.0, 0.0)	0.3 (0.0, 0.7)	0.3 (0.0, 0.7)	0.1 (0.0, 0.4)
Binge drinking[+] (past 12-months)						
Yes	1372	38.0 (35.7, 40.4)	17.1 (12.2, 22.0)	23.9 (19.8, 28.0)	17.9 (14.4, 21.4)	27.4 (24.0, 30.8)
No	1548	44.0 (41.6, 46.3)	59.6 (53.4, 65.9)	59.2 (54.3, 64.0)	61.9 (57.6, 66.4)	57.7 (54.0, 61.4)
Don’t know	454	14.5 (12.8, 16.3)	18.4 (13.4, 23.5)	13.7 (10.1, 17.2)	17.2 (13.6, 20.8)	11.8 (9.4, 14.1)
Refuse to answer	93	3.4 (2.4, 4.4)	4.9 (1.6, 8.1)	3.3 (1.2, 5.4)	2.9 (1.5, 4.3)	3.1 (1.8, 4.4)

STATE LEGAL SALES STATUS						
State Legal Sales						
Legal sales	1690	47.8 (45.4, 50.2)	35.8 (32.2, 39.5)	64.2 (60.5, 67.8)	---	---
No legal sales	1777	52.2 (49.8, 54.6)	---	---	36.9 (34.2, 39.55)	63.14 (60.45, 65.83)
CANNABIS USE BEHAVIORS						
Cannabis use (past 30-day)						
Yes	1248	33.0 (30.9, 35.2)	25.7 (20.5, 31.0)	36.0 (31.5, 40.5)	28.8 (24.9, 32.8)	36.5 (32.9, 40.0)
No	2219	67.0 (64.8, 69.2)	74.3 (69.0, 79.5)	64.0 (59.5, 68.5)	71.2 (67.2, 75.1)	63.6 (60.0, 67.1)
Cannabis use frequency[++]						
Never	1609	50.3 (47.9, 52.7)	57.2 (51.0, 63.4)	45.3 (40.3, 50.3)	57.1 (52.7, 61.5)	47.4 (43.7, 51.1)
Used more than 12 months ago	610	16.7 (14.9, 18.5)	17.1 (11.9, 22.4)	18.7 (15.0, 22.4)	14.1 (10.9, 17.2)	16.2 (13.6, 18.7)
Past 12-month use	352	8.0 (6.9, 9.1)	6.9 (4.0, 9.9)	8.0 (5.9, 10.0)	8.9 (6.6, 11.2)	7.9 (6.1, 9.7)
Monthly	211	6.2 (5.1, 7.4)	4.6 (1.7, 7.6)	7.1 (4.8, 9.5)	4.6 (2.7, 6.5)	7.2 (5.2, 9.1)
Weekly	173	4.5 (3.6, 5.4)	4.0 (2.2, 5.7)	5.2 (3.3, 7.2)	3.5 (1.9, 5.0)	4.6 (3.2, 6.1)
Daily/almost daily	512	14.4 (12.7, 16.0)	10.2 (6.6, 13.8)	15.7 (12.3, 19.0)	11.9 (8.9, 14.9)	16.8 (14.0, 19.6)

NOTES:

CI: Confidence Interval

*Asian, American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, multiple ethnicities, and "other"

**Income adequacy: Participants were asked "thinking about your family's income, how difficult or easy is it to make ends meet?"

[+]Binge drinking: Participants who used alcohol in the P12M were asked frequency of binge drinking (males=5/females=4/intersex=4-5). Responses categorized into groups for never, any binge drinking in the P12M, don't know, and refuse to answer

[++]Cannabis use frequency variables were mutually exclusive. Variable was derived from three survey questions that assess ever, current, and recent use. For "Daily/almost daily", participants responding to how often they use cannabis checked the box for "every day or almost every day".

All vars missing at less than 2% except: Hispanic ethnicity (2.7%), income adequacy (3.9%), mental health issue (3.3%), and binge drinking (3.4%). Sex, age group, race, state legal sales, cannabis use, and cannabis use frequency did not have missing data.

Table 4- 2. Unweighted sample sizes and weighted proportion (%) and confidence intervals (CI) for sociodemographic and cannabis use characteristics of past 12-month cannabis (P12m) users from the International Cannabis Policy Study (ICPS Wave 4 2021), by state legal sales status and age group (n=1,248)

	P12M Users Overall (n=1,248)		**Legal Sales States** (n=623)		**No Legal Sales States** (n=625)	
			18-20 years old (n=173)	21-25 years old (n=450)	18-20 years old (n=202)	21-25 years old (n=423)
	n	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**
SOCIODEMOGRAPHIC CHARACTERISTICS						
Sex						
Female	965	60.7 (56.6, 64.8)	66.4 (53.5, 79.4)	53.4 (46.0, 60.8)	77.4 (69.4, 85.5)	57.5 (51.2, 63.8)
Male	283	39.3 (35.2, 43.4)	33.6 (20.6, 46.6)	46.6 (39.2, 54.0)	22.6 (14.5, 30.6)	42.5 (36.2, 48.8)
Age group						
18-20 years old	375	30.2 (26.7, 33.7)	28.5 (22.9, 34.1)	---	31.6 (27.2, 36.0)	---
21-25 years old	873	69.8 (66.4, 73.3)	---	71.5 (65.9, 77.1)	---	68.4 (64.1, 72.8)
Race/Ethnicity						
White	814	61.7 (57.9, 65.5)	66.7 (55.10, 78.3)	66.8 (59.9, 73.6)	51.0 (42.8, 59.1)	60.3 (54.3, 66.2)
Black or African American	220	23.0 (19.7, 26.3)	19.3 (9.46, 29.2)	15.5 (10.4, 20.7)	29.9 (22.1, 37.8)	28.0 (22.5, 33.6)
Other small groups*	214	15.3 (12.41, 18.1)	14.0 (5.13, 22.9)	17.7 (12.2, 23.3)	19.1 (12.0, 26.2)	11.7 (8.0, 15.5)
Hispanic Ethnicity						
Yes	270	24.0 (20.5, 27.4)	25.4 (16.0, 34.8)	27.2 (20.3, 34.0)	17.9 (11.8, 24.0)	23.3 (17.8, 28.7)
No	960	74.5 (71.1, 78.0)	74.0 (64.6, 83.4)	71.7 (64.9, 78.6)	79.6 (73.2, 86.1)	75.0 (69.39, 80.5)
Don't know	13	1.0 (0.4, 1.7)	0.6 (0.0, 1.4)	0.3 (0.0, 0.8)	2.5 (0.0, 5.1)	1.2 (1.2, 0.0, 2.5)
Refuse to answer	5	0.5 (0.0, 0.9)	0.0 (0.0, 0.0)	0.8 (0.0, 1.6)	0.0 (0.0, 0.0)	0.5 (0.0, 1.6)
Income Adequacy**						
Difficult/very difficult	360	27.5 (24.0, 31.0)	22.3 (11.9, 32.7)	30.1 (23.0, 37.1)	28.9 (21.5, 36.2)	26.4 (21.7, 31.1)
Neither easy nor difficult	428	33.0 (29.4, 36.5)	29.6 (20.05, 39.1)	33.8 (27.02, 40.6)	29.2 (22.0, 36.5)	35.2 (29.4, 41.0)

Easy/very easy	367	30.8 (27.2, 34.4)	36.2 (24.40, 48.0)	27.4 (21.3, 33.4)	27.5 (20.6, 34.4)	33.4 (27.4, 39.4)
Don't know	70	5.9 (4.1, 7.6)	8.2 (2.3, 14.1)	3.8 (1.5, 6.1)	12.1 (5.8, 18.4)	4.1 (1.9, 6.3)
Refuse to answer	23	2.9 (1.3, 4.4)	3.8 (0.0, 7.8)	4.9 (1.0, 8.8)	2.3 (0.0, 4.8)	1.0 (0.0, 2.1)
MENTAL HEALTH STATUS						
Mental health issue (past 12-months)						
Yes	916	67.9 (64.1, 71.7)	71.5 (60.1, 82.9)	63.1 (55.9, 70.3)	72.1 (64.8, 79.4)	69.1 (63.0, 75.1)
No	218	21.5 (18.0, 25.0)	15.2 (4.6, 25.8)	23.6 (17.1, 30.1)	20.4 (13.6, 27.2)	22.4 (16.6, 28.2)
Don't know	82	8.0 (5.8, 10.1)	10.5 (3.9, 17.0)	10.3 (5.4, 15.1)	6.4 (2.8, 10.0)	5.6 (3.0, 8.2)
Refuse to answer	32	2.6 (1.6, 3.7)	2.8 (0.3, 5.3)	3.1 (1.2, 4.9)	1.1 (0.0, 2.5)	2.9 (0.7, 5.1)
SUBSTANCE USE BEHAVIORS						
Cigarette use (past 30-day)						
Yes	189	12.7 (10.1, 15.2)	4.8 (1.7, 7.9)	11.8 (7.6, 16.1)	10.5 (6.4, 14.6)	17.3 (12.0, 22.5)
No	1050	86.8 (84.2, 89.4)	94.9 (91.8, 98.1)	88.1 (83.8, 92.3)	89.3 (85.1, 93.4)	81.4 (76.1, 86.7)
Don’t know	8	0.4 (0.1, 0.8)	0.3 (0.0, 0.8)	0.1 (0.0, 1.2)	0.2 (0.0, 0.6)	0.9 (0.0, 2.0)
Refuse to answer	1	0.1 (0.0, 0.4)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.4 (0.0, 1.2)
E-cigarette use (past 30-day)						
Yes	283	21.3 (18.1, 24.5)	15.8 (9.4, 22.3)	22.0 (15.9, 28.1)	29.5 (22.4, 36.5)	18.9 (13.6, 24.2)
No	959	78.1 (74.9, 81.3)	83. 6 (77.1, 90.1)	77.0 (70.8, 83.2)	70.5 (63.5, 77.6)	80.7 (75.4, 86.1)
Don’t know	4	0.2 0.0, 0.5)	0.6 (0.0, 1.4)	0.4 (0.0, 1.1)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Refuse to answer	2	0.3 (0.0, 0.8)	0.0 (0.0, 0.0)	0.6 (0.0, 1.7)	0.0 (0.0, 0.0)	0.4 (0.0, 1.2)
Alcohol use (past 30-day)						
Yes	497	35.4 (31.8, 39.0)	27.9 (18.7, 37.1)	36.9 (30.3, 43.5)	35.4 (27.9, 43.0)	36.8 (30.8, 42.7)
No	745	64.0 (60.4, 67.6)	71.5 (62.3, 80.8)	62.1 (55.4, 68.8)	64.6 (57.0, 72.1)	62.8 (56.9, 68.8)
Don’t know	3	0.2 (0.0, 0.4)	0.5 (0.0, 1.3)	0.3 (0.0, 0.8)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
Refuse to answer	3	0.4 (0.0, 0.9)	0.0 (0.0, 0.0)	0.7 (0.0, 1.9)	0.0 (0.0, 0.0)	0.4 (0.0, 1.2)
Binge drinking*** (past 12-months)						
Yes	729	57.3 (53.4, 61.1)	44.8 (33.3, 56.3)	59.7 (52.4, 67.0)	52.4 (44.3, 60.5)	61.8 (56.1, 67.5)
No	346	27.4 (23.9, 30.9)	41.7 (29.8, 53.7)	24.4 (18.1, 30.6)	31.0 (23.6, 38.4)	23.3 (18.6, 28.0)

Don't know	133	11.1 (8.8, 13.5)	10.4 (4.5, 16.4)	11.0 (6.4, 15.6)	15.2 (8.7, 21.7)	9.6 (6.3, 13.0)
Refuse to answer	40	4.2 (2.3, 6.4)	3.1 (0.6, 5.5)	4.9 (0.5, 0.3)	1.5 (0.0, 3.2)	5.2 (2.4, 8.1)
STATE LEGAL SALES STATUS						
State Legal Sales						
Legal sales	623	46.8 (42.8, 50.7)	28.5 (22.9, 34.1)	71.5 (65.9, 77.1)	---	---
No legal sales	625	53.3 (49.3, 57.2)	---	---	31.6 (27.2, 36.0)	68.4 (64.1, 72.8)
CANNABIS USE BEHAVIORS						
Mode of use[+] number of days used in past 12-months, mean (95% CI)						
Dried herb	807[++]	121.0 (112.1, 130.0)	88.9 (67.3, 110.4)	133.9 (118.8, 149.0)	92.1 (71.6, 112.5)	133.7 (117.7, 149.7)
Vaping oils/liquids	558	62.6 (55.9, 69.3)	66.5 (49.0, 84.0)	65.4 (54.4, 76.3)	63.7 (45.6, 81.8)	57.9 (46.5, 69.3)
Edibles/foods	707	31.4 (26.7, 44.3)	25.1 (13.8, 36.5)	33.8 (26.1, 41.4)	29.0 (17.8, 40.2)	32.4 (23.7, 41.0)
Concentrates (e.g., wax, shatter, budder)	353	38.5 (32.7, 44.3)	54.0 (36.2, 71.7)	40.0 (30.3, 49.7)	29.8 (16.5, 43.1)	35.3 (25.7, 44.9)
All other modes[+++]	588	46.1 (40.8, 51.4)	59.0 (41.4, 76.7)	46.7 (38.3, 55.1)	28.5 (17.7, 39.3)	49.0 (35.6, 58.4)
Number of modes used						
1 mode	234	20.4 (17.2, 23.6)	20.5 (11.1, 29.9)	18.1 (12.8, 23.4)	22.3 (15.4, 29.1)	21.82 (16.2, 27.4)
2 modes	216	17.4 (14.4, 20.3)	11.0 (6.2, 15.7)	17.7 (11.8, 23.5)	20.8 (14.0, 27.5)	17.8 (13.2, 22.5)
3 modes	199	18.3 (14.9, 21.7)	22.0 (9.6, 34.3)	19.6 (13.0, 26.1)	15.7 (9.9, 21.5)	16.9 (12.3, 21.5)
4 modes	179	15.9 (13.1, 18.7)	20.2 (11.9, 28.6)	11.3 (7.4, 15.2)	16.4 (10.4, 22.4)	18.6 (13.3, 23.9)
5 modes	124	9.9 (7.8, 11.9)	14.9 (7.8, 22.1)	9.2 (5.8, 12.6)	8.9 (3.9, 13.9)	9.0 (5.7, 12.3)
6+ modes	191	18.2 (14.8, 21.6)	11.4 (5.3, 17.5)	24.2 (17.1, 31.3)	16.0 (8.3, 23.7)	15.8 (11.4, 20.3)
Cannabis source: Family/friends						
Yes	670	49.6 (45.7, 53.5)	50.8 (39.0, 62.6)	43.8 (36.7, 50.9)	50.1 (42.0, 58.2)	54.2 (48.2, 60.2)
No	578	50.4 (46.6, 54.3)	49.2 (37.4, 61.0)	56.2 (49.1, 63.3)	49.9 (41.8, 58.0)	45.8 (39.8, 51.8)
Cannabis source: Dealer						
Yes	464	40.5 (36.7, 44.3)	35.2 (25.0, 45.4)	25.1 (18.5, 31.7)	49.8 (41.6, 57.9)	52.4 (46.4, 58.3)
No	784	59.5 (55.7, 63.3)	64.8 (54.6, 75.0)	74.9 (68.3, 81.5)	50.2 (42.1, 58.4)	47.6 (41.7, 53.6)

Cannabis source: Dispensary						
Yes	582	43.3 (39.5, 47.1)	38.5 (27.4, 49.7)	68.7 (61.5, 75.8)	25.0 (18.0, 31.9)	30.4 (25.2, 35.5)
No	666	56.7 (52.9, 60.5)	61.5 (50.3, 72.6)	31.4 (24.2, 38.5)	75.0 (68.1, 82.0)	69.7 (64.5, 74.8)
Cannabis source: Made it or grew it myself						
Yes	91	9.6 (7.0, 12.1)	9.8 (0.9, 18.9)	12.5 (7.3, 17.7)	3.2 (0.4, 6.1)	9.7 (6.0, 13.3)
No	1157	90.5 (87.9, 93.0)	90.1 (81.2, 99.1)	87.5 (82.3, 92.7)	96.8 (93.9, 99.6)	90.4 (86.7, 94.0)
Cannabis source: Internet delivery or mail order						
Yes	125	13.6 (10.4, 16.9)	15.5 (4.8, 26.2)	17.5 (10.6, 24.4)	9.5 (5.1, 13.9)	11.3 (6.9, 15.8)
No	1123	86.4 (83.1, 89.7)	84.5 (73.8, 95.2)	82.5 (75.6, 89.4)	90.5 (86.1, 94.9)	88.7 (84.2, 93.1)
Cannabis source: Some other source[++++]						
Yes	2	0.1 (0.0, 0.2)	0.3 (0.0, 1.0)	0.1 (0.0, 0.4)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
No	1246	99.9 (99.8, 100)	99.7 (99.0, 100)	99.9 (99.6, 100)	100 (100, 100)	100 (100, 100)
Cannabis source: None obtained in the past 12 months, don't know, refuse to answer						
Yes	79	6.7 (4.5, 8.9)	10.8 (2.0, 19.6)	4.6 (1.1, 8.2)	10.0 (4.1, 16.0)	5.6 (3.0, 8.2)
No	1169	93.3 (91.1, 95.5)	89.2 (80.4, 98.0)	95.4 (91.8, 98.9)	90.0 (84.0, 95.9)	94.4 (91.8, 97.0)
Percentage of cannabis used in the past 12 months from legal source, mean (95% CI)						
	731	68.1 (65.4, 70.8)	72.3 (65.1, 79.5)	81.4 (78.1, 84.7)	52.1 (43.2, 61.1)	56.1 (51.0, 61.1)

NOTES:

CI: Confidence Interval

*Asian, American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, multiple ethnicities, and "other"

** Income adequacy: Participants were asked "thinking about your family's income, how difficult or easy is it to make ends meet?"

*** Binge drinking: Participants who used alcohol in the P12M were asked frequency of binge drinking (males=5/females=4/intersex=4-5). Responses categorized into groups for never, any binge drinking in the P12M, don't know, and refuse to answer

[+]P12M users whose mode did not match those on the list were removed from analyses of mode (n=105)

[++]n=number of participants who used mode at least one day in the past 12 months

[+++]drops, capsules, sprays, drinks, hash or kief, tinctures, topical ointments, other

[++++]Other source, don't know, refused to answer, have not obtained cannabis in the past 12 months

Table 4- 3. Weighted proportions of past 12-month (P12M) users by each sociodemographic and behavior use characteristic from the International Cannabis Policy Study (ICPS) Wave 4 (2021), by legal sales status and age group (n=3,467). For example, among all females in legal sales states, 38.2% are P12M users

	EAs Overall (n=3,467)	**Legal Sales States** (n=1,690)		**Non-legal Sales States** (n=1,777)	
		18-20 years old	21-25 years old	18-20 years old	21-25 years old
Past 12-month cannabis user = yes	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**	**% (95% CI)**
Sex					
Female	34.8 (32.4, 37.2)	27.2 (21.9, 32.4)	38.22 (32.9, 43.6)	33.38 (28.8, 37.9)	37.36 (33.6, 41.1)
Male	30.6 (26.6, 34.5)	23.3 (12.3, 34.3)	33.73 (26.5, 41.0)	19.65 (12.1, 27.2)	35.29 (28.8, 41.7)
Age group					
18-20 years old	27.4 (24.1, 30.6)	25.7 (20.5, 31.0)		28.8 (24.9, 32.8)	
21-25 years old	36.2 (33.4, 39.1)		36.0 (31.5, 40.5)		36.5 (32.9, 40.0)
Race/Ethnicity					
White	34.3 (31.5, 37.1)	27.5 (20.9, 34.1)	37.5 (31.7, 43.2)	28.1 (23.2, 32.9)	38.2 (33.7, 42.7)
Black or African American	37.6 (32.7, 42.4)	30.7 (16.0, 45.3)	53.09 (41.8, 64.4)	30.6 (22.2, 39.0)	38.4 (31.1, 45.7)
Other small groups*	24.7 (20.1, 29.3)	16.8 (6.3, 27.3)	25.15 (17.0, 33.3)	28.4 (18.3, 38.4)	26.9 (18.5, 35.3)
Hispanic Ethnicity					
Yes	30.5 (26.0, 35.0)	19.0 (11.3, 26.7)	34.7 (25.3, 44.0)	22.9 (15.3, 30.4)	39.8 (31.5, 48.1)
No	34.5 (32.0, 37.0)	30.4 (23.5, 37.2)	38.0 (32.7, 43.2)	31.0 (26.2, 35.7)	35.4 (31.5, 39.3)
Don't know	17.1 (6.0, 28.2)	6.3 (0.0, 15.2)	4.7 (0.0, 12.4)	23.9 (1.5, 46.3)	48.0 (12.6, 83.3)
Refuse to answer	20.7 (0.0, 41.5)	0.0 (0.0, 0.0)	20.3 (0.0, 45.3)	0.0 (0.0, 0.0)	34.9 (0.0, 87.0)
Income Adequacy**					
Difficult/very difficult	39.7 (35.0, 44.3)	32.9 (18.9, 46.9)	46.3 (35.9, 56.6)	31.8 (23.8, 39.9)	41.2 (34.6, 47.8)
Neither easy nor difficult	30.7 (27.1, 34.2)	19.4 (12.7, 26.1)	34.5 (27.3, 41.6)	25.1 (18.7, 31.5)	36.8 (30.6, 43.0)
Easy/very easy	34.1 (30.0, 38.1)	34.4 (22.8, 46.0)	32.4 (25.0, 39.9)	32.1 (24.5, 39.8)	36.2 (29.6, 42.7)

Don't know	24.5 (17.8, 31.1)	20.2 (7.1, 33.3)	25.5 (9.5, 39.6)	29.0 (15.4, 42.6)	23.0 (12.1, 33.9)
Refuse to answer	24.7 (12.9, 36.4)	16.7 (0.3, 33.2)	33.4 (9.7, 57.1)	19.0 (0.1, 37.9)	20.4 (0.0, 42.6)
Mental health issue (past 12-months)					
Yes	37.3 (34.5, 40.1)	33.0 (25.7, 40.3)	36.7 (31.0, 42.4)	33.3 (28.1, 38.6)	42.3 (37.9, 46.8)
No	26.0 (21.8, 30.3)	13.2 (3.8, 22.7)	32.8 (23.9, 41.6)	24.3 (16.5, 32.2)	28.0 (20.9, 35.1)
Don't know	28.3 (21.3, 35.2)	23.6 (9.5, 37.7)	43.1 (26.2, 60.0)	16.4 (7.4, 25.5)	26.7 (15.3, 38.0)
Refuse to answer	26.4 (16.3, 36.5)	22.1 (3.1, 41.2)	30.2 (10.4, 50.1)	14.8 (0.0, 31.5)	29.1 (10.9, 47.2)
Cigarette use (past 30-day)					
Yes	69.7 (60.5, 78.9)	88.2 (72.4, 100.0)	59.4 (40.4, 78.4)	84.3 (72.4, 96.2)	72.5 (62.5, 82.6)
No	30.7 (28.5, 32.9)	24.8 (19.5, 30.1)	34.2 (29.6, 38.8)	26.8 (22.8, 30.8)	33.0 (29.5, 36.6)
Don’t know	33.5 (9.0, 58.0)	100 (100, 100)	8.9 (0.0, 27.5)	15.3 (0.0, 44.7)	48.8 (9.6, 88.0)
Refuse to answer	80.3 (36.4, 100.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0. 0.0)	100 (100, 100)
E-cigarette use (past 30-day)					
Yes	67.0 (60.4, 73.6)	60.3 (44.8, 75.7)	69.9 (56.7, 83.1)	68.6 (58.4, 78.8)	65.3 (53.2, 77.3)
No	29.0 (26.8, 31.2)	23.2 (17.8, 28.7)	31.7 (27.1, 36.3)	23.2 (19.2, 27.3)	33.1 (29.5, 36.6)
Don’t know	19.7 (0.0, 40.8)	100 (100, 100)	45.9 (0.0, 100.0)	0.0 (0.0. 0.0)	0.0 (0.0. 0.0)
Refuse to answer	75.6 (38.1, 100.0)	0.0 (0.0, 0.0)	84.8 (49.1, 100.0)	0.0 (0.0. 0.0)	100 (100, 100)
Alcohol use (past 30-day)					
Yes	54.5 (49.7 59.3)	50.0 (36.0, 64.1)	52.5 (43.3, 61.6)	64.9 (55.2, 74.6)	53.9 (46.9, 60.9)
No	27.1 (24.7, 29.4)	21.5 (15.9, 27.2)	30.2 (25.0, 35.4)	22.3 (18.2, 26.4)	30.6 (26.8, 34.4)
Don’t know	19.4 (0.0, 41.4)	100 (100, 100)	29.0 (0.0, 74.3)	0.0 (0.0. 0.0)	0.0 (0.0. 0.0)
Refuse to answer	70.1 (30.2, 100.0)	0.0 (0.0, 0.0)	100 (100, 100)	0.0 (0.0. 0.0)	100 (100, 100)
Binge drinking[+] (past 12-months)					
Yes	49.7 (45.8, 53.5)	39.8 (28.8, 50.7)	49.9 (42.5, 57.4)	53.4 (45.2, 61.7)	51.5 (45.8, 57.1)
No	20.6 (17.8, 23.3)	22.5 (14.7, 30.2)	21.9 (16.0, 27.8)	17.3 (12.8, 21.8)	20.6 (16.3, 24.8)
Don’t know	25.3 (20.1, 30.5)	14.6 (6.1, 23.1)	29.1 (17.4, 40.8)	25.5 (15.1, 35.8)	29.8 (20.5, 39.2)
Refuse to answer	40.2 (25.9, 54.6)	16.3 (0.7, 31.8)	53.1 (21.6, 84.5)	14.4 (0.0, 30.5)	61.0 (40.6, 91.3)

NOTES:

*Asian, American Indian or Alaskan Native, Native Hawaiian or Pacific Islander, multiple race/ethnicities, and other
**Income adequacy: Participants were asked “thinking about your family’s income, how difficult or easy is it to make ends meet?”
[+]Binge drinking: Participants who used alcohol in the P12M were asked frequency of binge drinking (males=5/females=4/intersex=4-5). Responses categorized into groups for never, any binge drinking in the P12M, don’t know, and refuse to answer

Table 4- 4. Logistic regression results with adjusted odds ratios (aORs) and 95% CI for cannabis use frequency, number of modes used, and cannabis source among all EAs, under-age EAs, and over-age EAs in legal states vs. non-legal states

	All EAs Legal sales state vs. Non-legal sales states (ref)*	Under-age EAs Legal sales state vs. Non-legal sales state (ref)**	Over-age EAs Legal sales state vs. Non-legal sales state (ref)**
	aOR (95% CI)		
Frequency of Cannabis Use (ref=Never user)			
Used more than 12 months ago	1.22 (0.996, 1.39)	1.17 (0.82, 1.66)	1.28 (0.99, 1.64)
Past 12-month user	1.15 (0.90, 1.48)	0.80 (0.52, 1.24)	**1.41 (1.03, 1.92)**
Monthly user	1.03 (0.76 1.40)	0.98 (0.54, 1.78)	1.08 (0.75, 1.55)
Weekly user	**1.46 (1.05, 2.04)**	1.53 (0.85, 2.74)	1.47 (0.98, 1.64)
Daily/almost daily user	1.15 (0.92, 1.44)	1.15 (0.76, 1.74)	1.19 (0.90, 1.56)
Number of modes of cannabis use			
1, 2, 3, 4, 5, or 6+ modes	**1.26 (1.02, 1.56)**	1.33 (0.88, 2.02)	**1.34 (1.04, 1.72)**
Cannabis source			
Family/friend	0.85 (0.67, 1.07)	1.26 (0.78, 2.05)	**0.74 (0.56, 0.98)**
Dealer	**0.41 (0.32, 0.52)**	0.71 (0.44, 1.12)	**0.32 (0.24, 0.44)**
Dispensary	**4.27 (3.32, 5.50)**	**2.14 (1.31, 3.48)**	**6.02 (4.40, 8.24)**
Grew it myself	**2.33 (1.51, 3.60)**	**6.58 (2.02, 21.39)**	**2.01 (1.24, 3.27)**
Internet delivery	**1.64 (1.17, 2.29)**	1.23 (0.54, 2.36)	**1.80 (1.21, 2.67)**

NOTES:
*Model adjusted for age group, sex, race, Hispanic ethnicity, mental health status, income adequacy, cigarette use, e-cigarette use, alcohol use, and binge drinking
**Model adjusted for sex, race, Hispanic ethnicity, mental health status, income adequacy, cigarette use, e-cigarette use, alcohol use, and binge drinking
Bolded estimates are statistically significant at the 0.05 level

Unweighted sample sizes used in analyses were as follows: Frequency of cannabis use/Past 12-month cannabis user: all EAs (n=3,180), under-age EAs (n=1,126), over-age EAs (n=2,054); Number of modes (out of P12M users): all EAs (n=1,074), under-age EAs (n=317), over-age EAs (n=757); cannabis source (out of P12M users): all EAs (n=1,164), under-age EAs (n=345), over-age EAs (n=819)

Table 4- 5. Linear regression modeling the difference of mode and legally sourced cannabis in legal states vs. non-legal states among all EAs, under-age EAs, and over-age EAs

	All EAs Legal vs. Non-legal sales states (ref)*	Under-age EAs Legal vs. Non-legal sales states (ref)**	Over-age EAs Legal vs. Non-legal sales states (ref)**
		β (95% CI)	
Mode of cannabis (Days used in past 12 months, mean)			
Dried herb	2.00 (-15.80, 19.79)	13.63 (-18.61, 45.88)	-2.55 (-24.27, 19.16)
Vapes (oils or liquids)	6.71 (-7.17, 20.59)	8.26 (-19.58, 36.09)	6.64 (-9.58, 22.85)
Edibles	-5.09 (-14.21, 4.02)	3.22 (-12.88, 19.33)	-4.16 (-15.32, 7.00)
Concentrates	9.04 (-2.98, 21.06)	**33.72 (10.33, 56.21)**	2.15 (-12.16, 16.46)
All other modes***	6.40 (-4.21, 17.01)	**35.32 (14.72, 55.93)**	-3.32 (-15.84, 9.19)
Legally sourced cannabis (%)	**24.63 (19.32, 29.94)**	**22.47 (10.52, 34.41)**	**25.60 (19.71, 31.50)**

NOTES:
*Models adjusted for age group, sex, race, Hispanic ethnicity, mental health status, income adequacy, cigarette use, e-cigarette use, alcohol use, and binge drinking
**Models adjusted for sex, race, Hispanic ethnicity, mental health status, income adequacy, cigarette use, e-cigarette use, alcohol use, and binge drinking
***Liquids taken orally, drinks, hash or kief, tinctures, topical ointments, or other
Bolded estimates are statistically significant at the 0.05 level
Unweighted sample sizes used in analyses were as follows: Mode of cannabis (among all past 12-month users): all EAs (n=1,074), under-age EAs (n=317), over-age EAs (n=757); legally sourced cannabis (among all past 12-month users): all EAs (n=731), under-age EAs (n=190), over-age EAs (n=541)

CHAPTER FIVE: MANUSCRIPT 3: THE EFFECTS OF CANNABIS ADVERTISING STRESS-RELIEF MESSAGING ON EMERGING ADULTS' BEHAVIORS AND PERCEPTIONS: AN EYE TRACKING EXPERIMENT

ABSTRACT

PURPOSE: In this era of cannabis legalization in the US, cannabis advertising is widespread. Emerging adults (EAs) are a growing population of cannabis users and are potentially susceptible to advertising messaging. The cannabis industry has used health and wellness messaging to promote product use, where claims such as stress relief, a common ailment reported among EAs, are commonly used. Using eye tracking technology, the purpose of this study was to test whether exposure to stress relief cannabis advertisements (ads) and attention, measured by eye fixations, was associated with increased belief in stress relief messaging, lowered harm perceptions, and greater intention to use cannabis among EAs under the legal age of purchasing cannabis (18-20 years old).

METHODS: Participants were randomized to either a control (cannabis availability messaging) or experimental group (stress relief messaging) to view two cannabis ads in the eye tracking lab. I collected eye fixation data (duration of fixations, fixation counts, and time to first fixation) using eye tracking technology and surveyed participants on their perceptions of the products' stress relief potential, the products' perceived relative harm, and their intention to use. Data analysis consisted of Wilcoxon rank sum tests to compare group means and linear regression to understand the association between the attentional eye tracking measures and perception outcomes.

RESULTS: Overall, 90 participants viewed the ads. No group differences were found for the fixation data nor for the perception outcomes by group. Regression results showed

an association between fixation duration and increased belief in stress relief (β=0.39; p=0.0285), lowered harm perceptions (β=-0.61; p=0.0016), and greater intention to use (β=0.87; p=0.0021) in the stress relief messaging group and no associations in the cannabis availability group. The stress relief messaging lowered harm perceptions among non-P30D users, which did not occur for non-P30D users who were exposed to the cannabis availability messaging (2.35 vs. 2.71, p=0.0550).

CONCLUSION: Stress relief messaging on cannabis advertising may influence intentions and perceptions among emerging adults 18-20 years old, as longer fixation times were associated with greater belief in stress relief messaging, lowered harm perceptions, and greater intention to use. Non-P30D cannabis users were particularly susceptible to beliefs in lowered harm from stress relief messaging. Recommendations for current and future state policy are to limit stress relief messaging on cannabis advertising and future research could study the effects from other types of advertising messaging on EAs.

Introduction

Cannabis is legal in some form in most US states. It is often promoted as beneficial for health and wellness, with industry claims that it will ease stress, help with relaxation, improve sleep, and enhance mood (Bierut et al., 2017; Luc et al., 2020; Moreno et al., 2018). Not only are health claims among the most common descriptions for cannabis products (Cavazos-Rehg et al., 2019; Liu et al., 2020; Luc et al., 2020), but many people believe that using cannabis offers stress relief (Fleszar-Pavlović et al., 2022; Hyman & Sinha, 2009; Walsh et al., 2017) and other benefits without risk to health (Carliner et al., 2017).

Emerging adults (EAs) are defined by their transitional stage of life, in between adolescence and not yet taken on all the responsibilities of adulthood (Arnett, 2000). EAs 18-25 years old are also a growing population of cannabis users in the US (Sherburne, 2023) and contain the largest proportion of cannabis users, with 24.1% who used in the past month (SAMHSA, 2022). EAs are also less likely to perceive harm from regular use of cannabis compared to adolescents or adults (SAMHSA, 2022). Among EAs, there is an association between support for legalization of cannabis and reduced harm perceptions (Rudy et al., 2021) and among those who use cannabis, a relationship between lowered perceived risk of harm and increased cannabis use (Parker & Anthony, 2018).

Previous research has found that there are associations between adult-use cannabis legalization, such as greater access to cannabis dispensaries and advertising

exposure, and increased cannabis intentions to use and use among adolescents, including EAs who are under the legal age to purchase cannabis (18-20 years old) (D'Amico et al., 2015; Manthey et al., 2023; Trangenstein et al., 2021). Advertising restrictions differ by state, but regulations may focus on avoiding youth appealing features, such as toys, balloons, fruit, etc. (NRS, 2020). While this imagery may be appealing to older adolescents, much of the current advertising content meant to influence adults who are over the legal age to purchase cannabis is also appealing to underage EAs (Liu et al., 2020).

Stress and anxiety are often regarded as synonymous as they result in similar symptoms (American Psychological Association, 2022; Temple et al., 2014). Many people report using cannabis to relieve symptoms of stress and anxiety (Leung et al., 2022). Young adults who use cannabis for stress and anxiety are also more likely to report cannabis use disorder compared to those who don't use cannabis for stress and anxiety (Jacobs et al., 2023). Stress is a common experience among college-aged youth (Beiter et al., 2015) and many EAs have reported stress relief as a primary reason for their cannabis use (Bolts et al., 2023; Malain et al., 2023; Wheeler et al., 2020). Based on this association, it is possible that cannabis advertising that uses stress relief messaging is an influential mechanism on EAs' perceptions and behaviors.

The Elaboration Likelihood Model (ELM) offers a guiding framework for understanding how advertising messages are cognitively processed and how visual elements or the overall messaging can influence the effectiveness of advertising (Petty

& Cacioppo, 1986). The ELM explains how an individual evaluates and processes a message by way of two processing routes: central and peripheral. The central processing route is the pathway though which personally relevant messages are understood and processed for decision-making (Flynn et al., 2011), and the perceived relevance of the message can motivate message processing by the viewer. An example of central route processing involves a person who is personally motivated to lose weight through physical activity, who then views an advertisement (ad) promoting reduced price gym membership. Exposure to the ad influences the individual's behavior through the central processing route, which might result in obtaining a gym membership. The peripheral processing route is the pathway by which there is often less personal relevance, but the message may still affect attitudes and influence decision-making (Petty & Cacioppo, 1986). This may occur through the use of a popular celebrity or a particular appealing design in an ad. These elements may catch the eye of the viewer, which accesses cognition through the peripheral processing route (Petty & Cacioppo, 1986). This is important for understanding advertising influence, because even if the message is not processed through the central processing route where there is typically a longer period for viewing and cognition, the peripheral processing route enables an eye-catching feature of an ad to attract just enough attention to potentially affect behavior change.

Eye tracking is a method used to understand attention, inattention, comprehension, and cognition of visual elements in experimental research (Duchowski, 2007; Holmqvist, 2011). Eye tracking technology measures rapid movements of the eye,

called saccades, as well as where the eye pauses or fixates on an object, called fixations (Carter & Luke, 2020; Duchowski, 2007). Using an eye tracker, depending on the use of either a headset or apparatus mounted on a computer monitor, participants are potentially unaware that the tracker is collecting detailed measurements of their eye movements (Higgins et al., 2014; Meernik et al., 2016). Depending on the desired variables of interest, eye trackers can measure how the eye moves across an object or video, where the eye fixates, for how long, and how often the individual will direct their gaze elsewhere and then return to view the same object again (Tobii, 2023).

Among many other uses in research, there is a wide range of application for eye tracking studies in public health for tobacco, alcohol, and cannabis advertising. Researchers have used eye tracking with various populations of interest to understand the effects of tobacco health warning labels (Hwang et al., 2018; Klein et al., 2017; Liu et al., 2021; Lochbuehler et al., 2017; Sillero-Rejon et al., 2021), visual attention to anti-smoking content in ads (Dutra et al., 2018), e-cigarette promotions and health warnings (Garrison et al., 2018; Keller-Hamilton et al., 2022), and alcohol and tobacco advertising (Bansal-Travers et al., 2016; Dutra et al., 2018; John et al., 2022; Kaufman et al., 2016; Thomsen & Fulton, 2007). Due to the usefulness of eye tracking in understanding viewing patterns of multiple elements of advertising, which cannot be garnered through self-reports by participants, researchers have recommended the use of eye tracking technology to bolster public health understanding of advertising communication effects on perceptions and behaviors (Kaufman et al., 2018).

Using a between groups experimental design, the purpose of this study was to: 1) test whether exposure to cannabis ad stress relief messaging and cannabis availability messaging was associated with fixations using eye tracking technology, 2) test whether exposure to stress relief messaging and cannabis availability messaging were associated with perceived relative stress relief, perceived relative harm, and intention to use, and 3) test the association between participant eye tracking measures (fixation duration and fixation count) and perceived relative stress relief, perceived relative harm, and intention to use. I hypothesized that exposure to stress relief messaging was associated with increased belief that the product could produce stress relief, lowered harm perceptions, and greater intention to use these cannabis products. Additionally, I hypothesized that greater fixation duration and number of fixations on the stress relief messaging was associated with increased stress relief beliefs, lowered harm perceptions, and greater intention to use. Table 5.1 lists the research questions, data collection tools, measures, and analyses used in this study.

Methods

Participants and Recruitment

Undergraduate students at a university located in an adult-use legal state were recruited using SONA (Psychology Experiment Sign-Up System) (SONA, 2022) and through classroom presentations. Inclusion criteria consisted of participants who were: 1) 18-20 years old, 2) English speaking, 3) able to be calibrated on the Tobii eye tracker,

and 4) able to follow computer prompts and answer survey questions using a computer. Participants read and acknowledged their consent to participate (University of Nevada, Reno Institutional Review Board, Protocol #1938497-2) before viewing the ads or answering questions.

Apparatus

Eye tracking is a valuable tool that can be used to understand attention and provides information on eye movement and fixations (Duchowski, 2007; Holmqvist, 2011). Increased fixation duration, or length of attention, may also indicate increased cognitive processing (Stevens et al., 2020) and increased ability to recall what was viewed in the future (Carter & Luke, 2020). Time to first fixation of an object, another important measure of attention, signifies a feature's eye-catching ability (Holmqvist, 2011). Fixation counts can also be measured, which is the number of times the viewer fixates on an object, turns their attention elsewhere, and then returns to the same object for an additional fixation. Fixation counts are important as a greater number of counts signifies a potential increase in cognitive processing and a desire to understand what is being viewed (Holmqvist, 2011). Theoretically, increased attention to elements of an ad may indicate message processing through the central processing route of the ELM (Petty & Cacioppo, 1986).

The Tobii eye tracker was used to collect eye tracking information and Tobii Studio software was used to collect and output visual data for the variables of interest. The Tobii eye tracker sampled the data at 60 Hz, and the Tobii fixation classifier had a

velocity threshold of 35 pixels/window and distance threshold of 35 pixels. The eye tracker collects and averages data from both eyes, but if only one eye was detected, only one eye's data were recorded. The Tobii eye tracker included a desktop mount that fits below the computer monitor and does not incorporate the use of head mounting equipment. The ads fit in the center of the 11x21-inch computer monitor screen and did not fill the screen as they were 9 inches by 4 inches. Participants sat about 21 inches away from the first monitor that showed the ads and the second monitor with the lab survey sat adjacent and to the right of the first monitor. Tobii Studio was used for stimulus (ad) presentation and acquiring the data. See Figure 5-1 for example eye tracking lab experiment with participant.

FIGURE 5- 1. EXAMPLE OF PARTICIPANT VIEWING ADS IN THE EYE TRACKING LAB

Experimental materials

The ads were created by a contracted graphic designer (*99Designs*, 2022). The proposal to the designer outlined the project and provided specific guidelines for

desired ad design and included example cannabis ads with desirable features. Ad specifications included 1) all features on the experimental and control "Circle Cannabis" and "Cannabis Cloud" branded ads had to have the same size, font, and location placement on both ads; 2) the additional messages, such as age limitations for purchase and promotional websites were placed in small print to mimic ads in real life; 3) no graphics could be in the background of the experimental and control photos or text so that the effects of the messaging on the outcomes could be isolated; 4) no other messaging would be included on the ads that would explicitly promote health or wellness; and 5) all ads would contain branding, so that ads were similar to what is seen in real life. The designer was given artistic freedom to create the ads, including branding images, photos, colors, fonts, and placement. The design process went through multiple iterations and included feedback from committee members.

Ads in the experimental condition contained the messages, "Live Stress Free" and "Relax and Unwind" and the control condition ads both contained the message, "Now in Northern Nevada." The experimental message was chosen to represent the notion that use of the product will help relieve stress, something that is commonly experienced among college-aged youth (Beiter et al., 2015). The control condition contained a message that does not promote stress relief nor any other wellness-related message. Ads are shown in Figure 5.2 and Table 5.2 shows message distribution for the ads.

Figure 5- 2. Experimental and control group ads: A) Circle brand experimental group ad; B) Circle brand control group ad; C) Cloud brand experimental group ad; and D) Cloud brand control group ad

A

B

C

D

Text Message	Experiment Ad A: Circle	Control Ad B: Circle	Experiment Ad C: Cloud	Control Ad D: Cloud
"Live Stress Free"			X	
"Relax and Unwind"	X			
"Now in Northern Nevada"		X		X

Table 5- 1. Experimental and control group text messages

Procedure

Participants completed a Qualtrics survey (Appendix A) at least one day before their visit to the lab, where sociodemographic information (age, race/ethnicity, gender), perceived stress (using Cohen's 10-item stress scale) (Cohen et al., 1983), and substance use behavior (alcohol, tobacco, and cannabis) data were collected. Participants were asked about perceived stress prior to participating in the experiment to avoid any potential effects on the outcomes due to participation in the survey. On their scheduled in-person eye tracking lab appointment, participants were randomized to experimental or control condition and instructed to sit in front of the computer monitor where Tobii was installed. The calibration procedure included measuring five points located in various places on the monitor and re-calibration occurred for participants who were not calibrated on one or more points. After successful calibration, participants followed the prompts on the monitor. Participants viewed two cannabis ads and their eye movements were recorded. Each ad was displayed for ten seconds, which is a time limit commonly used for viewing stimuli in eye tracking studies (Dutra et al., 2018; Stevens et al., 2020), and each ad was followed by instructions to answer survey questions

recorded on Qualtrics (Appendix B), which were displayed on an adjacent computer monitor. Participant incentives included UNR research credits through SONA or class extra credit. Figure 5.3 illustrates the experiment flow, which includes data collected and participant and researcher roles.

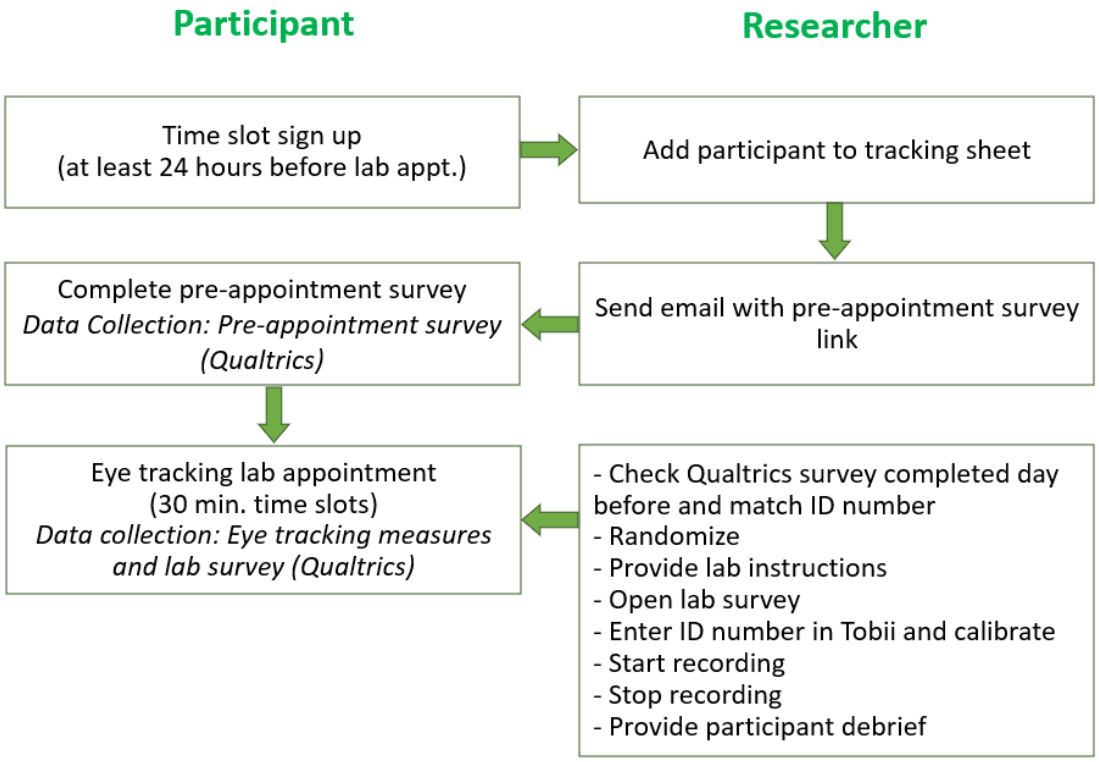


Figure 5- 3. Eye tracking lab experiment flow chart

Measures

Perception outcomes

Perceived relative stress relief (PRSR). Participants were asked, "Compared to other cannabis products, how well do you think THIS product relieves stress?" Responses were on a 5-point scale and included: "much better"; "better"; "about the

same"; "worse"; and "much worse." Scores were coded so that higher scores related to lowered PRSR of the product; mean scores for both ads in each condition were used in analyses.

Relative harm perception (RHP). Participants responded to the following question, "Compared to other cannabis products, how harmful do you think THIS product is?" Responses were on a 5-point scale and included: "much less harmful"; "less harmful"; "about the same"; "more harmful"; and "much more harmful." Scores were coded so that lower scores related to less perceived relative harm of the product and mean scores for both ads in each condition were used in analyses.

Intention to use. Participants were asked about intention to use cannabis with the question, "How much do you agree with this statement. I want to use this cannabis product." Response options were on a 5-point scale and included: "strongly agree"; "agree"; "neither agree nor disagree"; "disagree"; and "strongly disagree." Scores were coded so that higher scores related to increased intention to use the product and mean scores for both ads in each condition were used in analyses. This question was adapted from a tobacco ad appeal experiment (Moran et al., 2021).

Eye tracking measures

Areas of Interest. Areas of interest (AOIs) were drawn around the features of interest and contained the eye tracking data used in analyses (further described in the *Data analysis* section below). AOIs were used to designate the boundary of the eye

tracking measures. For example, when measuring FD, only fixations meeting the threshold in time (100 ms) and contained within the photo AOI were reported by the eye tracking software and used in analyses of the photo. In Figure 5-4, the AOIs are pictured as colored boxes and include the areas specific to study analyses (picture and text).

Attention. Attention was analyzed using three measures: 1) Fixation Duration (FD), 2) Fixation Count (FC), and 3) Time to First Fixation (TTFF). FD was measured with a minimum threshold of 100 milliseconds (ms), which is within the 100-300ms threshold range commonly used to classify a fixation (Duchowski, 2007; Rayner, 1998). FD values are a cumulative measure of fixations, meaning that the measure corresponds to the total time a participant fixates on the area of interest, regardless of whether they look away from the area. For a fixation to be included in this measure, the participant must have fixated for the minimum threshold. FC is the number of times a participant fixates on an AOI and is measured in counts. Fixations are counted each time a participant fixates on an AOI. This means that participants can fixate within an AOI, look away from the AOI, and then return to fixate their attention back to the AOI, with each visit counted. Higher FC is associated with the desire to understand what is being viewed and/or the saliency of the message (Holmqvist, 2011). TTFF measures the amount of time in seconds a participant first fixates within an AOI. TTFF measures the eye-catching ability of an AOI, where shorter TTFF times may equate with a more eye-catching feature (Holmqvist, 2011). For FD, FC, and TTFF, I used the mean values for photos and

text for both ads in analyses, with an exception of RQ 1, where photo and text are listed separately.

Other variables of interest

Other variables. I used the pre-test survey to collect additional information from participants, such as gender, race/ethnicity, smoking status, e-cigarette use, alcohol use, and cannabis use. Perceived stress was measured using the Perceived Stress Scale (PSS 10) (Cohen et al., 1983) to control for participant stress, as participant awareness of stress level may affect the perception outcomes. The 10-item PSS was used due to proof of the measures' validity (Simon, 2021) and improved psychometric properties compared to the 14-item PSS (Lee, 2012).

Statistical analysis

Sample size calculation. Sample size was calculated a priori using G*Power (Faul, 2020). I used a two-tailed t test, comparing means for perceived relative stress relief (PRSR), a significance level of 0.05, effect size 0.6, and power 0.80. The result was a sample size of 90, 45 participants in each group.

Data management. I reviewed a sample of video recordings captured by Tobii and the raw data for quality control. For some participants, TTFF was recorded as "0", which strongly suggests that the participants' eyes were already fixated on that area as the ad appeared on the screen. This event occurred 62 times out of the total 360 AOIs

(17%) that were viewed (four AOIs viewed by each of the 90 participants) and since there were no significant differences by condition (9.4% vs 7.8%; p-value=0.9623), these instances were removed from TTFF analyses.

Data analysis. Using tools in Tobii Studio, areas of interest (AOIs) were drawn around the features of interest on the ads: photo and text message. Each of the AOIs shown in Figure 5.4 are contained within a colored box, although boxes were not seen by participants. AOIs were used to designate a boundary around an object where eye tracking measures will be collected and outputted for analysis. For example, any eye tracking measures that occurred within the orange shading on the photo in the Circle brand experimental ad were used in the analyses that included the photo AOI. Regardless of color, a box around one of the AOIs, for example the text message in the experimental Cloud brand ad, is the exact same size and in the same location in the control version of the text in the Cloud brand ad.

Each participant viewed either two experimental or two control ads. For each eye tracking measure (FD, FC, and TTFF), the resulting mean from the photos and the text messages were used in analyses. For example, the FD for a participant in the experimental group was the result of taking the mean FD of the two photos and two text messages. The same process was used for the perception outcomes and the resulting means were used in analyses.

I used descriptive statistics to understand study sample characteristics. Chi square and Fisher's Exact tests were used to compare experimental and control group

sociodemographic characteristics and substance use behaviors and t-tests were used to analyze perceived stress level differences. The groups did not differ except by gender. I then checked the effects of gender on the outcomes by including gender as a predictor variable in the regression model and found no effect.

To answer Research Question 1 (RQ1), I reported the proportion of people who fixated (where 1=at least one fixation occurred and 0=no fixations occurred) on the texts or photos. In RQ2, recall was tested by reporting the proportion of correct recall by group condition. In RQ3, I reported mean ms of FD and TTFF for the AOIs for both ads combined and FC was reported as mean count. I used Wilcoxon Rank Sum texts for non-parametric data to understand any differences in means by group condition. For the perception outcomes in RQ4, I used the mean responses from both ads and compared means using Wilcoxon Rank Sum tests. In RQ5, I used linear regression to understand the relationship between FD and FC and the perception outcomes: RPSR, RHP, and IU. Finally, for RQs 6 and 7, I reported means for FD, FC, TTFF, and perceptions outcomes and compared the means among P30D users and non-P30D users in each condition using Wilcoxon Rank Sum tests. I used SAS v. 9.4 to perform all statistical analyses (SAS, 2015).

Table 5- 2. Eye tracking experimental study research questions, data collection tools, measures, and analyses

#	Research Question	Data Collection Tool(s)	Measure(s)	Analysis
1	Do participants fixate on the stress relief/non-stress relief features while viewing the advertisement?	Tobii eye-tracker	Fixation Count (FC): 0=no fixations on either photo/text; 1=one or more fixations on photo/text Fixation: at least 100ms	Percentage (%) of participants in each condition who fixated on the photo or text.
2	Are participants consciously aware of the stress relief message in the ad?	Qualtrics survey	Recall: 1=correct recall for 1 or 2 ads; 0=no correct recall for either ad	Percentage (%) of participants in each condition who correctly recalled messaging for one or both ads
3	Is there a difference in fixation duration (FD), fixation count (FC), and time to first fixation (TTFF) on the AOIs in the experimental vs. control conditions?	Tobii eye-tracker	Independent variable: condition Dependent variable: Means for all areas of interest (AOI) for fixation duration (FD), FC, and time to first fixation (TTFF)	Compare group means for FD, FC, and TTFF
4	Is there a significant difference in perceived relative stress relief (PRSR), relative harm perception (RHP), and intention to use (IU) in the experimental vs. control conditions?	Qualtrics survey	Independent variable: condition Dependent variable: PRSR, RHP, and IU	Compare group means for PRSR, RHP, and IU
5	What is the relationship between fixation (FD and FC) and perceptions outcomes (PRSR, RHP, and IU) in the experimental and control conditions?	Tobii eye-tracker, Qualtrics survey	Independent variable: Mean FD and FC for all AOIs Dependent variable: Mean PRSR, RHP, IU	Linear regression to model the relationship between FD and FC and PRSR, RHP, and IU in the experimental group and in the control group

6	Is there a difference in FD, FC, and TTFF in each condition by P30D cannabis use status?	Tobii eye-tracker	Independent variable: condition Dependent variable: Means for all AOIs of interest for FD, FC, and TTFF	Compare group means for FD, FC, and TTFF among P30D users and non-P30D users
7	What are the differences in PRSR, RHP, and IU in each condition by past 30-day (P30D) cannabis use?	Qualtrics survey	Independent variable: condition Dependent variable: Mean PRSR, RHP, and IU	Compare group means for PRSR, RHP, and IU among P30D users and non-P30D users

FIGURE 5- 4. AREAS OF INTEREST (AOI) FOR EACH CANNABIS ADVERTISEMENT

Ad A: Experimental group Circle brand

Ad B: Control group Circle brand

Ad C: Experimental group Cloud brand

Ad D: Control group Cloud brand

Note: For each branded ad, the AOI (photo and text message) is the same size and has the same location placement.

Results

Table 5.3 shows descriptive statistics for the study sample (n=90). There were no statistically significant differences between characteristics of the experimental (stress relief messaging) and control group (cannabis availability messaging), except for gender. Overall, the sample was majority 20 years old, women, non-Hispanic White, past 30-day alcohol users, and non-past 30-day e-cigarette, tobacco cigarette, and cannabis users.

Tests for normality using the Shapiro-Wilk test revealed FD and FC to be normally distributed and TTFF, relative stress relief, relative harm perceptions, and intention to use not normally distributed.

Fixation on the ad and awareness of the message

Almost all participants fixated on at least one of the photos and text messages on the two ads they viewed except for one participant in the control group who did not fixate on photo (Table 5.4). When recall is compared to eye fixation, the result is that only one participant in each group incorrectly recalled the ad's message. Participants both fixated at least once on the areas of interest and recalled the messaging correctly, suggesting that participants paid attention to and understood the ads' messaging

Fixation outcomes

Table 5.4 describes results concerning how participants viewed the ads using eye tracking. There were no statistically significant differences between groups for FD

(1323ms vs. 1371ms; p=0.6165), FC (4.8 vs. 4.8; p=0.5519), nor TTFF (2117ms vs. 2104ms; p=0.6193). Group condition was not a factor in participants' viewing patterns.

Perception outcomes

Although none were statistically significantly different, participants in the stress relief messaging group believed that the product ads they viewed offered more stress relief (3.50 vs. 3.37, p=0.5624) and were less harmful (2.35 vs. 2.56, p=0.1767) compared to the cannabis availability group. Participants in both groups mostly reported that the ads had no effect on their intention to use these cannabis products (2.83 vs. 2.57, p=0.2356) (Table 5.4).

Association between fixations and perception outcomes

In the stress relief messaging group, every one second increase in FD was associated with greater belief in stress relief (β=0.39; p=0.0285), lowered harm perceptions (β=-0.61; p=0.0016), and greater intention to use (β =0.87; p=0.0021) for the cannabis products. Additionally, greater fixation counts were associated with greater intentions to use in the stress relief messaging group (β=0.19; p=0.0226). There was no statistically significant association between FD or FC and the perception outcomes in the cannabis availability group (Table 5.5).

Fixation outcomes and cannabis use status

In both the stress relief and cannabis availability messaging group, there was no difference in fixation or eye-catching ability of the features by past 30-day cannabis use status (Table 5.6).

Perception outcomes and cannabis use status

In Table 5.6, among participants in the cannabis availability group, there was a statistically significant difference in relative harm perception by current cannabis use. P30D users in this group were more likely to believe that the product was less harmful than other products compared to non-P30D users (2.27 vs. 2.71, p=0.0274). However, in the stress relief messaging group, there was no difference in harm perceptions by P30D cannabis use. In other words, the stress relief messaging eliminated the difference in perceived harm between P30D users and non-users. Further, when I compared harm perceptions of the stress relief and cannabis availability groups among non-P30D users to understand if there were differences in harm perceptions between groups, the result approached statistical significance (2.35 vs. 2.71, p=0.0550). Therefore, the stress relief messaging lowered harm perceptions, regardless of cannabis user status, while the cannabis availability messaging did not. Additionally, there were significant differences in both groups for intention to use, where P30D users had greater intention to use the product in the stress relief (3.28 vs. 2.50; p=0.0065) and cannabis availability (3.13 vs. 2.27; p=0.0050) groups compared to non-P30D users.

Discussion

Overall, there were no differences between groups for the eye tracking measures or perceptions outcomes. However, for participants in the stress relief messaging group, there were significant associations between increased fixation duration and greater belief in stress relief potential of the products, lowered perceptions of harm, and positive intentions to use. There were no associations found among these measures for the participants in the cannabis availability messaging group. P30D cannabis users in both groups had greater intentions to use cannabis compared to non-P30D users. Additionally, the stress relief messaging lowered harm perceptions among non-P30D users relative to non-users who saw the cannabis availability messaging.

Although not significantly different between groups, there were trends towards increased beliefs in stress relief, lowered harm perceptions, and greater intentions to use in the stress relief vs. cannabis availability messaging group. A possible explanation for the lack of significant difference in perceptions between the groups relates to currently held beliefs around cannabis. Previous research has shown that cannabis harm perceptions have decreased over time among all age groups (Carliner et al., 2017) and many EAs use cannabis to relieve stress (Bolts et al., 2023). Potentially, reinforcement of the stress relief messaging in the current study was not enough to further influence those beliefs.

Longer fixation times were associated with increased belief in the stress relief messaging, lowered perceived harm, and intention to use, which highlights the effects of the ads' messaging. Increased attention, or longer fixation duration, is associated with potential increased cognitive processing of the message (Holmqvist, 2011; Stevens et al., 2020) and future recall of the messaging (Carter & Luke, 2020). Implications from these findings are that ads with eye-catching features that can capture and potentially keep viewers' attention may influence perceptions and behaviors. Further, since ads that feature people are more appealing and attract more attention than ads without people (Chen-Sankey et al., 2022; Moran et al., 2021), ads that contain health claims via text that are accompanied by photos of people may be particularly influential.

In both the experimental and control groups, P30D cannabis users had greater intentions to use the products in the ads compared to non-P30D users. Another finding of note was that stress relief messaging lowered harm perceptions among non-P30D users in the stress relief messaging group but not among non-users in the cannabis availability group. Perceived harmfulness of cannabis has been decreasing in previous decades throughout the US (Rudy et al., 2021; Schuermeyer et al., 2014) and it is likely that stress relief messaging on cannabis advertising is also associated with lowered perceived harm from use.

There are a few limitations to this study's findings. First, the two ads (Cloud and Circle brands) were similar in design, with similar features and color tones, although each contained a different color scheme. It is possible that more drastic changes in the

ads' design would have resulted in different outcomes. Second, the ads were designed in a way that design features would not overlap. The effects from overlapping features (i.e., text messaging with multiple colors and design features in the background) would be problematic for interpreting the eye tracking results. For instance, a "busier" background design may have caused longer fixation times because participants were distracted by the background design or maybe even shorter fixation times due to participant confusion resulting in inattention to the features. Third, participants viewed the instruction screen and directly after would view the ad which was in the same location on the monitor as the instructions. As a result, for some participants, their eyes were already focused on an area of interest and their TTFF would read 0 seconds. These participants were excluded from TTFF analysis due to the low probability that they would be able to view the feature that quickly. Fortunately, this did not result in the removal of a large percentage of data. A remedy for this occurrence would have been to place the instructions on another section of the screen or to place an object on the screen before the ad that would shift the eyes away from the center of the screen where the ad would then appear. Fourth, participants viewed the ads in a quiet space without distraction, while outside the lab environment, ads would be viewed on a billboard or on a website with the viewer's partial attention. To help mitigate this difference, I added a time limit to viewing the ads. Last, the sample of under-age college students living in an adult-use legal state in this study may not be representative of under-age EAs in the larger US population.

Conclusions

Longer fixation times on the stress relief messaging were associated with greater belief in stress relief, lowered perceived harm, and increased intention to use cannabis. Among non-P30D cannabis users, the stress relief messaging lowered perceived harm relative to the cannabis availability messaging on the ads. While there were no differences in the perception outcomes by group condition, the use of eye tracking technology provided valuable information on the relationship between longer viewing times, or attention, and the perception outcomes. These findings can be used to inform future advertising regulations, as avoiding appeal and potential use of cannabis among under-age EAs is important for public health. Future research could benefit from using eye tracking to test the effects of additional claims made on cannabis advertising among emerging adults.

Table 5- 3. Study sample sociodemographic characteristics and substance use behaviors (n=90)

	Total (n=90)	Experimental Group (n=47)	Control Group (n=43)	
	n (%)	**n (%)**	**n (%)**	**p-value**
Gender				
Women	60 (66.7)	37 (78.7)	23 (53.4)	0.0174*
Men	29 (32.2)	10 (21.3)	19 (44.2)	
Non-binary/third gender	1 (1.1)	0 (0.0)	1 (2.3)	
Age				
18 years old	27 (30.0)	18 (38.3)	9 (20.9)	0.1576
19 years old	21 (23.3)	11 (23.4)	10 (23.3)	
20 years old	42 (46.7)	18 (38.3)	24 (55.8)	
Race/Ethnicity				
Non-Hispanic White	43 (47.8)	22 (46.8)	21 (48.8)	0.9007
Hispanic/Latino	19 (21.1)	12 (25.5)	7 (16.3)	
Non-Hispanic Asian	9 (10.0)	5 (10.6)	4 (9.3)	
Non-Hispanic Black	3 (3.3)	1 (2.1)	2 (4.7)	
Non-Hispanic American Indian/Alaska Native	1 (1.1)	0 (0.0)	1 (2.3)	
Non-Hispanic other race/ethnicity	2 (2.2)	1 (2.3)	1 (2.3)	
Multiple race/ethnicity	13 (14.4)	6 (12.8)	7 (16.3)	
Perceived Stress Score mean (SD) (scores: 0-13 low stress, 14-26 moderate stress, 27-40 high stress)	18.2 (6.0)	18.8 (6.1)	17.4 (5.8)	0.7617
Alcohol use (past 30-days)				
Yes	62 (68.9)	32 (68.1)	30 (69.8)	0.8637
No	28 (31.1)	15 (31.9)	13 (30.2)	
E-cigarette use (past 30-days)				
Yes	30 (33.3)	19 (40.4)	11 (25.6)	0.1392
No	60 (66.7)	28 (59.6)	32 (74.4)	
Tobacco cigarette use (past 30-days)				
Yes	13 (14.4)	8 (17.0)	5 (11.6)	0.4691
No	77 (85.6)	39 (83.0)	38 (88.4)	
Cannabis use (past 30-days)				
Yes	35 (38.9)	20 (42.6)	15 (34.9)	0.4579
No	55 (61.1)	27 (57.4)	28 (65.1)	

Table 5- 4. Participant outcomes by experimental and control group condition (n=90)

	Experimental Group (n=47)	**Control Group** (n=43)	
	n (%)	**n (%)**	**p-value**
Fixate (yes)			
Photo	47 (100)	42 (98)	
Text	47 (100)	43 (100)	
Correct Recall (yes)	46 (98)	42 (98)	
	Mean (SD)	**Mean (SD)**	
Eye Tracking Measures			
Fixation duration (ms)	1323 (463)	1371 (513)	0.6165
Fixation count (count)	4.8 (1.6)	4.8 (1.7)	0.5519
Time to first fixation (ms)	2117 (1921)	2104 (1542)	0.6193
Perception Outcomes			
Stress Relief	3.50 (0.60)	3.37 (0.64)	0.5624
Harm perception	2.35 (0.67)	2.56 (0.62)	0.1767
Intention to use	2.83 (0.98)	2.57 (0.97)	0.2356

Table 5- 5. Linear regression modeling the association between fixation duration (FD) and fixation count (FC) and relative stress relief, relative harm perception, and intention to use

	Relative Stress Relief		**Relative Harm Perception**		**Intention to Use**	
	Experimental Group	Control Group	Experimental Group	Control Group	Experimental Group	Control Group
	B (95% CI) p-value					
Fixation Duration (seconds)	**0.39 (0.04, 0.75) p=0.0285**	0.02 (-0.35, 0.39) p=0.9039	**-0.61 (-0.99, -0.23) p=0.0016**	-0.23 (-0.58, 0.12) p=0.2044	**0.87 (0.31, 1.42) p=0.0021**	0.24 (-0.33, 0.80) p=0.4086
Fixation Count	0.08 (-0.02, 0.18) p=0.1214	-0.01 (-0.12, 0.11) p=0.8963	-0.10 (-0.20, 0.02) p=0.1044	-0.06 (-0.17, 0.05) p=0.2523	**0.19 (0.03, 0.35) p=0.0226**	0.10 (-0.07, 0.27) p=0.2413

Table 5- 6. Experimental and control group mean responses for FD, FC, TTFF, relative stress relief, relative harm perception, and intention to use by past 30-day cannabis use status

	Experimental Group			**Control Group**		
	P30D Cannabis Users (n=20)	**Non-P30D Cannabis Users** (n=27)		**P30D Cannabis Users** (n=15)	**Non-P30D Cannabis Users** (n=28)	
	Mean (SD)	Mean (SD)	p-value	Mean (SD)	Mean (SD)	p-value
Eye Tracking Measures						
Fixation duration (ms)	1369 (451)	1289 (477)	0.5685	1334 (528)	1391 (513)	0.7792
Fixation count (count)	5.0 (1.4)	4.6 (1.8)	0.1742	4.7 (1.8)	4.9 (1.7)	0.5657
Time to first fixation (ms)	1813 (1499)	2343 (2183)	0.4014	2635 (2116)	1819 (1067)	0.4522
Perception Outcomes						
Stress Relief	3.35 (0.49)	3.61 (0.66)	0.2043	3.50 (0.63)	3.30 (0.64)	0.4664
Harm perception	2.35 (0.63)	2.35 (0.72)	0.7702	2.27 (0.68)	2.71 (0.53)	**0.0274**
Intention to use	3.28 (0.88)	2.50 (0.93)	**0.0065**	3.13 (0.83)	2.27 (0.92)	**0.0050**

CHAPTER SIX: DISCUSSION AND CONCLUSIONS

Introduction

The purpose of this research was to understand the effects from cannabis legalization, with a focus on emerging adults (EAs). In the first study, I used a scoping review protocol to search, extract, chart, and summarize scientific articles on the effects of cannabis advertising exposure on cannabis-related perceptions, attitudes, intentions, and behaviors. In the second study, I used data from the International Cannabis Policy Study (ICPS) to understand differences in cannabis-use behaviors among under- (18-20 years old) and over-age (21-25 years old) EAs by adult-use legal sales status. In the final study, I used eye tracking technology to test the effects of stress relief messaging on cannabis advertisements (ads) on cannabis-related perceptions. Using an experimental, between groups study design, eye fixations were recorded and participants were asked about their belief in the product's stress relief potential, relative perceived harm perceptions, and intentions to use the products.

EAs are a unique population emerging from adolescence and entering adulthood (Arnett, 2000). As a group, they are often overlooked in research or they are combined with either adolescent or adult population groups. Cannabis-related policy regulations and public health programs are often aimed at prevention among adolescents and treatment programs among adults. This can be a short-sighted approach, as the needs

of EAs in relation to cannabis-related health information and education vary from other age groups and adaptive approaches would offer more direct and age-appropriate benefits. Since the proportion of EAs who use cannabis in the US is larger than those among adolescents and adults (SAMHSA, 2022), states could address this gap by creating regulations and supporting public health interventions that specifically address the needs of EAs.

Summary and discussion

In manuscript one, *A scoping review of the effects of cannabis advertising on perceptions and behaviors*, I used a scoping review protocol to chart and summarize data on the effects of cannabis advertising exposure on cannabis-related perceptions, attitudes, and behaviors. The presence of cannabis advertising is relatively new in the US and the effects are not well understood compared to alcohol and tobacco marketing and advertising, of which there is abundant evidence on the effects (Finan et al., 2020; Lovato et al., 2011; Petticrew et al., 2017). Additionally, cannabis ad messaging frequently uses more direct messaging to promote the benefits of use on health and wellness (Liu et al., 2020; McQuoid et al., 2023) compared to tobacco and alcohol advertising. The summary of studies in this review shows significant effects from advertising exposure, describes what kinds of study designs were utilized and discusses the strength of their associations, and highlights limitations of the measurements used.

Cannabis advertising exposure was associated with positive cannabis-related perceptions, attitudes, intentions, and behaviors among various age groups. There were four longitudinal, one experimental, one qualitative, and 11 cross-sectional study designs included in this review. Almost all of the studies used participant self-reported recall of advertising (billboards, magazines, internet, cannabis storefront, etc.), which is subject to recall bias and potential limited memory accuracy.

Study findings highlight multiple theoretical associations in the Conceptual Model from Chapter Two (Figure 2-1). The first set of associations found in this study describe the effect of advertising exposure, as a result of legalization of cannabis sales, on perceptions, such as *perceived risks/harm*, *perceived benefits* from use, *attitudes*, and *outcome expectancies,* and the behavioral factors, such as *intention to use* and *cannabis use*. Advertising is a form of persuasive communication (*Encyclopedia: Advertising Effects*, 2019), which has effects on perceptions and behaviors through its ability to evoke emotion (Poels & Dewitte, 2019) and increase awareness and knowledge of a product (Wright-Isak, 1997). Another pathway described in the model that may provide additional insight on these associations, although not studied in this review, shows that advertising exposure may affect perceptions and behaviors through *perceived social norms* related to cannabis use. State-sanctioned cannabis advertising may increase perceptions that cannabis use is socially acceptable since local governments effectively support sales and use. Increase acceptance of use, in turn, can

lead to more positive *attitudes*, greater perceived *benefits* from use, lowered *harm perceptions,* greater *intention to use*, and increases in cannabis use *behaviors*.

Future research on the effects of cannabis advertising exposure could use eye tracking technology to test the effects on perceptions and behaviors among various age groups of specific features and messaging on cannabis ads. Portable eye tracking devices could be used to help quantify the frequency and amount, or dose, of advertising exposure and viewers' attention to the ads, measured by eye fixations. Other studies might investigate various levels of exposure to health and wellness messaging and follow up with participants to understand behavioral effects. Since the cannabis industry is growing and more states are poised to legalize adult-use cannabis sales, which means an increase in advertising, it is worthwhile to develop effective methods that if used, result in a better understanding of how cannabis advertising affects perceptions and behaviors.

The results from the scoping review may also inform current and future advertising regulations. The study findings show that overall, cannabis advertising exposure is associated with positive perceptions and behaviors, although from the body of research on this topic, it is unclear what features of the ads are most influential. A better understanding of the specific influences of cannabis advertising would lead to advertising regulations that more adequately protected those most vulnerable. In Nevada, where adult-use cannabis sales are legal, advertising regulations currently include limits on using images of balloons, toys, and cartoons on ads (NRS, 2020). This

regulation is useful for adolescents and children, who may find this imagery particularly appealing or eye-catching, but for older adolescents and EAs, this regulation likely does not limit appeal. The definition of appeal could be broadened to include features that are appealing to older adolescents and EAs, which would more adequately minimize youth exposure to influential messaging. The results of this scoping review also revealed that exposure to multiple modes of advertising was associated with increased use. Advertising regulations in cannabis-legal states could address this influential factor by limiting advertising density. Similar to bans on tobacco advertising in newspapers in the late 1990's (Carvajal, 1999) and on television by the US government in 1971 (Library of Drug Policy, 1972), cannabis advertising could also be limited, which would minimize higher frequency of exposure.

Manuscript two, *Cannabis use among emerging adults in US states with and without legal cannabis sales using the International Cannabis Policy Study (ICPS) wave 4 2021 data*, used US data from the ICPS, an online survey distributed in Canada, New Zealand, Australia, and the US. The survey aims to understand the impacts of cannabis legalization on cannabis use prevalence, use patterns, cannabis modes of use, perceptions and attitudes, and more. Survey data has been collected annually beginning in 2018 and includes participants 16-65 years old. I used US data from wave 4 (2021) and sampled EAs 18-25 years old. The aim was to understand differences in EAs' cannabis use behaviors (cannabis use frequency, modes used, multi-modal use, cannabis source, and cannabis source legality) by adult-use legal sales status and age

group (EAs 18-20 and 21-25 years old). This study contributes to the field by specifically examining EAs and further, by age of legal cannabis purchase. This is important as EAs are often combined with adolescent or adult samples, which fails to account for EAs' life stage that includes increased susceptibility to substance use.

The ICPS study resulted in multiple findings on cannabis use behaviors that were associated with adult-use legal sales. Compared to under-age EAs in non-legal states, under-age EAs in legal states had higher odds of using cannabis in the past 12 months (compared to never users), used concentrates and other modes such as liquids, drinks, hash or kief, tinctures, etc. on more days in the past 12 months, obtained more cannabis from dispensaries and growing it themselves, and obtained more of their cannabis from legal sources. Over-age EAs in legal states had higher odds of using multiple cannabis modes, obtained less cannabis from family, friends, and dealers, had higher odds of obtaining cannabis from dispensaries, growing it themselves, or internet delivery, and obtained a greater proportion of cannabis from legal sources than over-age EAs living in non-legal states.

Study findings can be explained by the associations depicted in the Conceptual Model (Figure 2-1), where the outcomes of this study are all behavioral factors from the model. The outcomes analyzed (use frequency, multi-modal use, cannabis mode used, cannabis source, and amount of legal cannabis sourced) were all found to be associated with adult-use legal sales status. The outcome effects were also moderated by under- or over-age status, suggesting that adult-use legal sales affected use behaviors

differentially by age. Even though the current ICPS study did not investigate other associations from the model, the effects on behaviors from legalization were likely mediated by environmental factors, perceptions, and intentions to use. For example, behaviors could be influenced by increased acceptance of cannabis use (*perceived social norms*) due to state governments allowing sales and advertising. Similarly, legalization laws and advertising exposure may affect perceptions and behavioral factors, where there are lowered *perceived harms* from use, increased beliefs in the *benefits* from use, and greater *intentions to use*. These perceptions effects then lead to increases in *cannabis use* behaviors.

While there were no large differences between cannabis use frequency in legal and non-legal states, there are important implications for some of the other differences in use. More EAs may be initiating cannabis use in legal states and using multiple modes, which is likely due in part to the increase in cannabis availability in legal states (Manthey et al., 2023). Another important finding was that under-age EAs reported obtaining more cannabis from legal sources, greater use of dispensaries, and using more concentrated cannabis in legal states. There are a few potential explanations for the increase in dispensary access, such as inadequate or missing age verification checks in dispensaries, obtaining cannabis from over-age friends, possessing a medical cannabis card, where the age requirement is typically lower than 21 years, or accessing illegal dispensaries, which are often indistinguishable from legal dispensaries (Nicholas et al., 2021).

Findings from ICPS study suggest topics for future research investigations. Researchers could investigate under-age EAs' experiences obtaining cannabis, their perceptions of the social norms around use, and their perceptions of social pressure in adult-use legal states. Findings from this research may provide valuable insights into the driving mechanisms of use in states that allow legal sales among an under-studied population.

Study findings also suggest multiple policy implications. Research findings from investigations on under-age EAs' access to legal cannabis may lead to changes in cannabis industry regulations, such as stricter enforcement on age verification checks for dispensary entry. Potentially, research investigating the non-legal cannabis marketplace could result in findings of increased sales, which might result in funding for increased surveillance and law enforcement involvement. Since use of cannabis concentrates is higher among under-age EAs in legal states compared to non-legal states and more frequent use of high potency products is associated with increased risk of adverse mental health effects (Wilson et al., 2019), policies might include limits on THC concentration in products as well as limits on the amount of concentrated cannabis that can be purchased by individuals. Other policies might include posting educational messages in dispensaries on the health effects from more frequent use of high potency products. Further cannabis-related research would likely support changes in current policies and inform regulations and polices for states with newly enacted cannabis laws.

The third manuscript, *The effects of cannabis advertising stress-relief messaging on emerging adults' behaviors and perceptions: An eye tracking study*, used eye tracking technology to test the effects of stress relief messaging on cannabis ads on under-age EAs (18-20 years old). Participants were recruited from the University of Nevada, Reno and randomized to view ads with stress relief or cannabis availability messaging while their eye movements were tracked. Areas of interest (AOIs) were drawn around features of the ads that relayed either stress relief or cannabis availability messaging and the eye tracking data collected included fixation duration (FD), fixation counts (FC), and time to first fixation (TTFF), which each measure different aspects of attention. After each of the two ads were viewed, participants answered survey questions about relative stress relief potential of the product in the ad, relative perceived harm perceptions, and intention to use the product.

There were 90 participants who viewed the ads, 47 in the stress relief messaging group and 43 in the control group. No group differences in the fixation data nor for the perceptions outcomes were found. However, associations were found between FD and FC and the perceptions outcomes. In the stress relief messaging group, longer FD predicted increased belief in stress relief, lowered harm perceptions, and greater intention to use these products. Also in the stress relief messaging group, increased FC predicted greater intention to use. These associations were not found among participants who viewed the cannabis availability messaging. Additionally, while the stress relief messaging lowered harm perceptions among non-P30D users in the stress

relief messaging group, the cannabis availability messaging did not lower harm perceptions among non-P30D users in the control group.

The eye tracking study findings show similar associations as those depicted in the Conceptual Model (Figure 2-1). Exposure to cannabis advertising with stress relief messaging in this experiment was associated with perceptions, such as the increased belief in stress relief (*attitudes*) and lowered *perceived harm,* and behavioral factors, such as *intention to use*. Exposure to the cannabis availability messaging was not associated with perceptions or intentions, indicating that advertising messaging has differential effects on perceptions. Additionally, cannabis use moderated the association between exposure to stress relief messaging and harm perceptions, where study findings showed that current cannabis users had lowered perceptions of harm.

Cannabis is often promoted by the industry as a product that eases stress and anxiety, improves sleep, and offers other health benefits (Bierut et al., 2017; Luc et al., 2020; Moreno et al., 2018). The level of influence of this type of messaging on under-age EAs is not well understood and therefore, this study offers a significant contribution to the field. Findings can inform current and future cannabis advertising regulations, where there may be benefits to limiting stress relief messaging and other similar health and wellness messaging on advertising. Future research efforts could investigate effects on perceptions as well as measure and analyze the behavioral effects from other types of commonly used cannabis advertising health and wellness messaging.

Conclusion

Understanding the effects of cannabis legalization among emerging adults (EAs) is important for public health and has implications for future research and state policy. EAs are in between adolescence and adulthood and are particularly susceptible to increased use and lowered harm perceptions from use (Arnett, 2005; SAMHSA, 2022). One of the mechanisms in which legalization can have effects on EAs is through cannabis advertising, where exposure to advertising and targeted messaging may further influence EAs' perceptions of harm, cannabis use expectancies, intentions, and use behaviors. Cannabis advertising restrictions aim to reduce appeal and exposure among children and adolescents, which is a short-sighted approach and fails to adequately address the influence of advertising and marketing on EAs. The research in this dissertation shows that cannabis advertising exposure is associated with lowered harm perceptions and increased use behaviors, suggesting a need to revisit policies related to cannabis advertising. Current and new policy recommendations might include further limiting advertising content and density and revisiting the definition of youth appeal to incorporate younger EAs who are under the legal age to purchase cannabis. I also found that EAs' cannabis use patterns were associated with adult-use legal sales. Findings showed increased concentrated cannabis use, multi-modal use, dispensary use, and legal cannabis used in legal adult-use states compared to non-legal states. These findings support the need for further research with under-age EAs to investigate legal and non-legal cannabis access and perceived social norms around cannabis use. And

finally, using eye tracking technology, I found that longer fixation duration on cannabis ads with stress relief messaging was associated with greater belief in stress relief, lowered harm perceptions, and increased intention to use. Future research could endeavor to understand the influence of other types of health and wellness messaging on cannabis advertising on EAs and current and future policies might add or create limits on stress relief messaging on cannabis ads. As more US states are primed to legalize cannabis for adult-use, it becomes more important than ever to understand the effects of legalization on EAs in order to minimize advertising influence and ultimately reduce harm among a population at increased risk of use.

Appendix A

Eye Tracking: Qualtrics pre-appointment survey

********** ***Qualtrics Instructions*** **********

What is your age?

- ○ Under 18 years old
- ○ 18
- ○ 19
- ○ 20
- ○ 21 years or older

Please read the following information about this study and indicate your consent to participate.

The purpose of this study is to understand perceptions of cannabis advertisements. If you volunteer for this study, you will be asked to complete two different tasks. The first task is the following survey, which takes 5-10 minutes to complete. The second task involves in person participation in the CAMS lab, Reynolds School of Journalism and will take 10-15 minutes to complete.

This study is considered to be minimal risk of harm. This means the risks of your participation in the research are similar in type or intensity to what you encounter during your daily activities.

Although results of the study may be published, no names or identifying information will be included in the publication or shared with the public. Your participation is completely voluntary, and you may withdraw your consent and discontinue participation at any time. If you have questions, concerns, or complaints about this research, you may report them (anonymously if you so choose) by calling the University of Nevada, Reno Research Integrity Office at 775.327.2368.

Please indicate your consent to participate below.

○ I understand this information and consent to participate in this study under the conditions stated above.

○ I do not consent to participate.

ID Please enter the last 4 digits of your Wolf Card/Student ID card. This is for data matching purposes only and will be kept confidential.

_____

Race/Eth How would you describe your race/ethnicity? (Choose all that apply)

☐ Non-Hispanic White

☐ Non-Hispanic Black

☐ Non-Hispanic Asian

☐ Non-Hispanic American Indian/Alaska Native

☐ Non-Hispanic Native Hawaiian/Pacific Islander

☐ Hispanic/Latino

☐ Non-Hispanic other race/ethnicity: (please fill in)

_____

Gender How would you describe your gender?

- ○ Man
- ○ Woman
- ○ Non-binary / third gender
- ○ I describe my gender some other way: (please fill in)

_____

The next set of questions ask you about your feelings and thoughts during THE LAST MONTH. In each case, please indicate your response by checking the box representing HOW OFTEN you felt or thought a certain way.

For each question choose from the following responses.

	Never	Almost never	Sometimes	Fairly often	Very often
In the last month, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
In the last month, how often have you felt nervous and "stressed"?	○	○	○	○	○
In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
In the last month, how often have you felt that things were going your way?	○	○	○	○	○

continued...

	Never	Almost never	Sometimes	Fairly often	Very often
In the last month, how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
In the last month, how often have you felt that you were on top of things?	○	○	○	○	○
In the last month, how often have you been angered because of things that were outside of your control?	○	○	○	○	○
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

The next set of questions will ask about your substance use behaviors.

When was the last time you had a drink of any kind of alcohol, like beer, wine, or liquor, even 1 sip?

- ○ I have never had a drink of alcohol
- ○ More than 1 year ago
- ○ More than 30 days ago, but less than 1 year ago
- ○ Within the past 30 days

****** *Asked this question if response above is: "Within the past 30 days"* ******
During the past 30 days, on about how many days did you drink alcohol, even 1 sip?

- ○ 1-5 days
- ○ 6-10 days
- ○ 11-20 days
- ○ 21-29 days
- ○ All 30 days

When was the last time you smoked a tobacco cigarette, even 1 puff? Do not include e-cigarettes or vaping products here.

- ○ I have never smoked tobacco cigarettes
- ○ More than 1 year ago
- ○ More than 30 days ago, but less than 1 year ago
- ○ Within the past 30 days

****** *Asked this question if response above is: "Within the past 30 days"* ******
During the past 30 days, about how many days did you smoke a tobacco cigarette, even 1 puff?

- ○ 1-5 days
- ○ 6-10 days
- ○ 11-20 days
- ○ 21-29 days
- ○ All 30 days

When was the last time you vaped nicotine, such as in an e-cigarette or vape, even 1 puff?

- ○ I have never used electronic vapor products with nicotine
- ○ More than 1 year ago
- ○ More than 30 days ago, but less than 1 year ago
- ○ Within the past 30 days

****** *Asked this question if response above is: "Within the past 30 days"* ******
During the past 30 days, about how many days did you vape nicotine, even 1 puff?

- ○ 1-5 days
- ○ 6-10 days
- ○ 11-20 days
- ○ 21-29 days
- ○ All 30 days

When was the last time you used any type of cannabis product (also called marijuana, weed, pot, chronic), like in a joint, bong, pipe, edibles, vapes, or concentrates?

- ○ I have never used cannabis
- ○ More than 1 year ago
- ○ More than 30 days ago, but less than 1 year ago
- ○ Within the past 30 days

****** ***Asked this question if response above is: "Within the past 30 days"*** ******
During the past 30 days, about how many days did you use any type of cannabis product, even 1 time?

- ○ 1-5 days
- ○ 6-10 days
- ○ 11-20 days
- ○ 21-29 days
- ○ All 30 days

********** ***End of Survey*** **********

Appendix B

Eye Tracking: Lab survey

********** ***Qualtrics Instructions*** **********

Welcome to the CAMS lab!

The purpose of this study is to understand perceptions of cannabis advertisements. This part of the study will take approximately 10-15 minutes to complete.

Although results of the study may be published, no names or identifying information will be included in the publication or shared with the public. Your participation is completely voluntary, and you may withdraw your consent and discontinue participation at any time. If you have questions, concerns, or complaints about this research, you may report them (anonymously if you so choose) by calling the University of Nevada, Reno Research Integrity Office at 775.327.2368.

Please indicate your consent to participate below.

○ I understand this information and consent to participate in this study under the conditions stated above. (4)

○ I do not consent to participate. (5)

Please enter the last 4 digits of your Wolf Card/Student ID card.

********** ***Prompt to view Ad 1 on*** **********

Please respond to the following questions about what you just saw.

What information do you remember seeing in this advertisement?

- ○ The product was on sale
- ○ The product relieves stress
- ○ Can buy the product in northern Nevada
- ○ The product's THC concentration

Compared to other cannabis products, how harmful do you think **this** product is?

- ○ Much less harmful
- ○ Less harmful
- ○ About the same
- ○ More harmful
- ○ Much more harmful

Compared to other cannabis products, how well do you think **this** product relieves stress?

- ○ Much better
- ○ Better
- ○ About the same
- ○ Worse
- ○ Much worse

Compared to other cannabis products, what do you believe the price of **this** product is?

- ○ Much less expensive
- ○ Less expensive
- ○ About the same
- ○ More expensive
- ○ Much more expensive

Compared to other cannabis products, what is the THC concentration in **this** product?

- ○ Much lower THC concentration
- ○ Lower THC concentration
- ○ About the same
- ○ Higher THC concentration
- ○ Much higher THC concentration

How much do you agree with this statement:
I want to use this cannabis product.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

You are finished with the questions.

Return to monitor 1 and press the space bar.

********** ***Prompt to view Ad 2*** **********

Please respond to the following questions about what you just saw.

What information do you remember seeing in this advertisement?

- ○ The product was on sale
- ○ The product relieves stress
- ○ Can buy the product in northern Nevada
- ○ The product's THC concentration

Compared to other cannabis products, how harmful do you think **this** product is?

- ○ Much less harmful
- ○ Less harmful
- ○ About the same
- ○ More harmful
- ○ Much more harmful

Compared to other cannabis products, what do you believe the price of this product is?

- ○ Much less expensive
- ○ Less expensive
- ○ About the same
- ○ More expensive
- ○ Much more expensive

Compared to other cannabis products, how well do you think **this** product relieves stress?

- ○ Much better
- ○ Better
- ○ About the same
- ○ Worse
- ○ Much worse

Compared to other cannabis products, what is the THC concentration in **this** product?

- ○ Much lower THC concentration
- ○ Lower THC concentration
- ○ About the same
- ○ Higher THC concentration
- ○ Much higher THC concentration

How much do you agree with this statement:
I want to use this cannabis product.

- ○ Strongly agree
- ○ Agree
- ○ Neither agree nor disagree
- ○ Disagree
- ○ Strongly disagree

Let the lab manager know that you are finished.

Thank you!

********** ***End of Qualtrics Survey*** **********

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