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A SURVEY OF CANNABIS CONSUMPTION AND IMPLICATIONS OF AN EXPERIMENTAL POLICY MANIPULATION AMONG YOUNG ADULTS

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A thesis proposal submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

by

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List of Abbreviations

AIC	Akaike Information Criterion
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
APA	American Psychiatric Association
BIC	Bayesian Information Criterion
BSSS	Brief Sensation Seeking Scale
CBD	cannabidiol
CBHSQ	Center for Behavioral Health Statistics and Quality
CBN	cannabinol
CSA	Controlled Substances Act
DSM-IV	Diagnostic and Statistical Manual for Mental Disorders, fourth ed.
DSM-5	Diagnostic and Statistical Manual for Mental Disorders, fifth ed.
FDA	US Food and Drug Administration
LCA	Latent Class Analysis
MTF	Monitoring the Future
NSDUH	National Survey on Drug Use and Health
OZ	ounces
THC	tetrahydrocannabinol
TPB	Theory of Planned Behavior
US	United States
YRBS	Youth Risk Behavior Survey

Abstract

A SURVEY OF CANNABIS CONSUMPTION AND IMPLICATIONS OF AN EXPERIMENTAL POLICY MANIPULATION AMONG YOUNG ADULTS

By Alyssa Rudy B.S.

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Major Director: Dr. Caroline Cobb, Assistant Professor, Department of Psychology

The purpose of this online cross-sectional study was to identify cannabis user profiles by administration method and examine how differential cannabis policies influence intentions among young adults. Participants were assigned randomly to one of three hypothetical cannabis policy conditions (recreationally legal; medically legal; illegal). Within conditions, participants completed measures regarding cannabis use, including administration methods, cannabis attitudes, norms, perceived behavioral control, self-efficacy, and intentions. Latent class analysis (LCA) was used to determine sub-groups of past 30-day cannabis users by administration method followed by sub-group comparisons. Condition effects on intentions and associated variables were examined using ANCOVA. Four classes (Low-Blunt, Low-Bong, Mod-Poly, High-Poly) differing in demographics and tobacco use were identified. Recreationally and medically legal policy conditions resulted in more favorable cannabis attitudes, higher self-efficacy, and higher intentions to use compared to the illegal policy condition. Results inform cannabis intervention efforts and longitudinal research on the effects of cannabis policy changes.

Introduction

Overview and Motivation

Cannabis, a well-known drug class used for recreational and medicinal purposes, is the most frequently used illegal drug in the United States (US; Center for Behavioral Health Statistics and Quality [CBHSQ], 2015). Prevalence trends demonstrate that in the past decade, past 12-month use of cannabis has increased from 4.1% to 9.5% among US adults (Hasin et al., 2015). Despite little change in US federal cannabis restrictions, during this same time, state-level cannabis policies have been evolving rapidly regarding medicinal use as well as recreational use. The changes in cannabis policy warrant investigation in order to reduce the potential harms of cannabis legalization. Cannabis policy changes affect the methods in which cannabis is consumed, patterns of cannabis use, and the types of individuals who consume cannabis (Borodovsky, Crosier, Lee, Sargent, & Budney, 2016; Hanson, 2016). [1] Differential consumption methods may be associated with different use patterns, health-related effects, and (e.g., demographic) predictors and correlates of cannabis use. Information is needed to address gaps in knowledge regarding cannabis user profiles by consumption method as well as examine how differential policy environments may influence cannabis use intentions, particularly among individuals at high risk for dependence such as young adults.

Cannabis: Cannabinoids, Concentrations, and their Health Effects

The cannabis plant (genus: *Cannabis*) has several well-characterized strains/species including *Cannabis sativa*, *Cannabis indica*, and *Cannabis ruderalis* (Sawler et al., 2015). Each

[1] Consumption refers to any type of cannabis use including inhalation, eating, and drinking. Ingestion refers to eating and drinking.

species contains different cannabinoid contents, and each prompt a variety of subjective effects. Pure *Cannabis sativa* elicits subjective cerebral effects while pure *Cannabis indica* varieties are well-known for their sedative effects (Sawler et al., 2015). Many varieties that are used for consumption are sexually propagated hybrids that contain genes from both cannabis sativa and cannabis indica (Cervantes, 2006; Emboden, 1974). *Cannabis ruderalis* is not consumed commonly due to its low levels (approximately 0.2%) of cannabis' primary psychoactive cannabinoid, Δ^9-tetrahydrocannabinol (THC; Beutler, 1978; Sawler et al., 2015). In all cannabis species, the flowering tops and leaves, which are harvested typically for consumption, contain the highest amounts of psychoactive cannabinoids (Adams & Martin, 1996). Cannabinoids, such as THC, are a class of chemical compounds that are found endogenously (e.g., anandamide) as well as from exogenous sources such as the cannabis plant that interact with specific cannabinoid receptors in the brain and other areas of the body (Ameri, 1999).

Cannabinoids, their receptors, and the physiological responses of the interaction between cannabinoids and cannabinoid receptors are contained in the endocannabinoid system (Aizpurua-Olaizola et al., 2016; Mechoulam & Parker, 2013). The cannabis plant contains over 400 chemical constituents of which over 109 are cannabinoids that interact with primarily two cannabinoid receptors: CB1 and CB2 receptors (El-Alfy et al., 2010; Mehmedic et al., 2010). Cannabinoid receptors are located in the central and peripheral nervous system of the body. CB1 receptors are mainly concentrated in the brain while CB2 receptors are located primarily in immune cells. Most research has focused on three cannabinoids in the cannabis plant: THC (primary psychoactive chemical), cannabinol (CBN; psychoactive but less powerful than THC), and cannabidiol (CBD; not psychoactive but has other therapeutic properties; Sharma, Murthy, &

Bharath, 2012). When extracted, THC is a volatile viscous oil that is highly lipophilic and can be detected in plasma within seconds after inhalation (via combusted cannabis; Grotenhermen, 2003; Sharma et al., 2012). Oral administration of cannabis results in a slower delivery of THC as well as time to peak plasma concentration (Grotenhermen, 2003). The lipophilic nature of THC is related to the distribution pattern within the body resulting in concentration in the brain and vascularized tissues (Grotenhermen, 2003). Metabolism rates vary dependent on the pattern of use, dose, and biological measure (e.g., plasma, urine), but urine assays can detect THC metabolites for up to 12 days following use (Law, Mason, Moffat, Gleadle, & King, 1984).

Cannabis consumption (mediated primarily by the cannabinoids consumed) affects the brain, body, and behavior in a variety of ways. Dose and route of administration are important to consider when examining effects associated with cannabis consumption. Some acute effects such as delusions, hallucinations, and depersonalization are observed typically at only high doses but are generally short lasting (Advokat, 2014). Recent reports of THC concentration in seized dried cannabis has increased from 3% in the 1980s to about 12% in 2014 (ElSohly et al., 2016; Volkow, Baler, Compton, & Weiss, 2014). In contrast, THC concentration for cannabis concentrates is between 60% and 80% (Stogner & Miller, 2015b). These differences in concentration may influence associated patterns of cannabis use and related health effects.

Acutely, cannabis use induces feelings of euphoria and relaxation and can result in impaired memory, decreased performance in cognitive tasks, decreased reaction time, and negative mood-type effects including panic and paranoia (Ameri, 1999; Sharma et al., 2012). The pleasurable and rewarding effects of cannabis, particularly THC, are linked primarily to the widespread use and abuse of this substance (Ameri, 1999; Cooper & Haney, 2009). Like other

drugs of abuse, THC activates the mesolimbic dopamine system, a brain area critical for reinforcing drug-taking behavior (Tanda, Pontieri, & Di Chiara, 1997). Other negative health effects of cannabis use include suppression of antibody production in the immune system, increased heart rate, and hypotension (Ameri, 1999; Franz & Frishman, 2016; Rieder, Chauhan, Singh, Nagarkatti, & Nagarkatti, 2010). Initiation of cannabis use among adolescents and young adults can also affect the developing brain resulting in impaired neuronal connectivity (Zalesky et al., 2012), particularly in the prefrontal cortex (Filbey & Yezhuvath, 2013; Gogtay et al., 2004).

Importantly, in addition to the effects associated with abuse potential and negative health consequences, cannabinoids also are associated with medically relevant and therapeutic health effects. Cannabis consumption can produce analgesic, antiemetic, and anticonvulsive effects (Ameri, 1999; Holland et al., 2006). Prior research suggests that cannabis consumption is beneficial for cancer patients who experience nausea and other negative side effects from chemotherapy treatments (Carlini & Cunha, 1981; Holland et al., 2006; Rivera-Olmos & Parra-Bernal, 2016; Schrot & Hubbard, 2016). Studies show that CBD helps combat Alzheimer's disease (Karl, Garner, & Cheng, 2016), multiple sclerosis (Patti et al., 2016), and epilepsy (Ameri, 1999; Leo, Russo, & Elia, 2016; Lippiello et al., 2016). This diverse range of positive and negative effects and the risks to younger populations who may initiate cannabis use creates challenges for cannabis policy and regulation as well as research efforts in this area.

In recent years, the availability of new recreational cannabis forms (i.e., concentrates) and consumption methods (i.e., electronic heating systems/vaporizers and concentrate/dab rigs) have increased with little data available concerning their relative health effects. Historically, cannabis

has either been consumed by combustion (i.e., smoked) or taken orally (often by mixing with food; Adams & Martin, 1996; Sharma et al., 2012). As described above, average THC concentration varies between dried leaves versus concentrates, and THC dose is vital to understanding the acute effects experienced. In one clinical demonstration, dried cannabis plants and synthetic THC preparations (controlling for THC concentration) that were either smoked or ingested orally (via brownies) produced similar dose-dependent effects and subjective effects when compared between products (i.e., dried cannabis vs. synthetic THC). Unfortunately, these results were not examined by consumption method (i.e., smoked THC vs. oral THC ingestion; Wachtel, ElSohly, Ross, Ambre, & de Wit, 2002). More research is needed on the differential health effects of cannabis forms (e.g., dried vs. concentrate) and methods of cannabis administration.

Most of the data available only have examined effects of dried and combusted cannabis. Similar to the health effects observed for combusted tobacco use, combusted cannabis use is associated with increased coughing and mucus, increased risk of lung disease, exposure to carbon monoxide, and the potential to develop lung cancer (Martinasek, McGrogan, & Maysonet, 2016; Yayan & Rasche, 2016). Other forms of cannabis use may elicit unique health effects. For example, oral cannabis consumption and/or cannabis chewing may not result in combustion-related side effects but instead produce mouth irritation and other adverse changes to the oral epithelium (Cho, Hirsch, & Johnstone, 2005). Data from an internet sample of cannabis users indicated an association between cannabis use via vaporizer (electronic heating system) and fewer respiratory symptoms controlling for a host of associated factors relative to cannabis users who did not use a vaporizer (Earleywine & Barnwell, 2007). The current literature on

effects of cannabis concentrates is small; however, preliminary studies suggest that use of cannabis concentrates contributes to a higher incidence of fainting, potential for higher cannabis withdrawal symptoms due to elevated THC content, potential dangers from consumption of products made with butane, and an increased risk of psychosis (Di Forti et al., 2015; Loflin & Earleywine, 2014; Miller, Stogner, & Miller, 2016; Stogner & Miller, 2015a). Taken together, these data support better assessment of cannabis use in terms of dose and consumption method to better understand the health implications of these use patterns. These data also indicate that there may be differential health effects between methods of cannabis administration; therefore, use patterns of these methods must be further explored.

Trends in Cannabis Use, Abuse, and Dependence

In concert with or potentially in response to evolving cannabis preparations and consumption methods, current (past 30-day) cannabis use among people over 12 years old has increased from 14.5 million in 2007 to 22.2 million in 2014 (CBHSQ, 2015). Among those aged 14 to 17 years in 2013, cannabis was the most highly used drug (NIDA, 2015). For young adults (aged 18-25), past month cannabis use was 20.8% in 2016, which is a 4.9 percentage point rise from 2004 (CBHSQ, 2015, 2017). Among US adults at large, past month cannabis use was 7.2% in 2016, an increase of almost 3.1 percentage points since 2002 (CBHSQ, 2017). Specifically, in Virginia, past 30-day cannabis use among 18-25 year olds was 17.8% in 2016, which is lower than national prevalence rates for this age group (See **Table 1**). Among adults aged 26 or older in Virginia, past 30-day cannabis use was also lower than nationwide rates in 2016. However, these nationwide and Virginian trends suggest that overall cannabis use in multiple age groups is increasing at a moderate rate.

Table 1. Nationwide and Virginian Prevalence Estimates of Cannabis Use by Age

	Nationwide estimates		Virginia estimates	
	Past year cannabis use	Past 30-day cannabis use	Past year cannabis use	Past 30-day cannabis use
Youth Aged 12-17	12.0%	6.5%	11.4%	5.4%
Young adults Aged 18-25	33.0%	20.8%	30.1%	17.8%
Adults Aged 26+	11.0%	7.2%	8.5%	6.7%

Note: Virginian estimates from the 2015 NSDUH (CBHSQ, 2016). Nationwide estimates from the 2016 NSDUH (CBHSQ, 2017).

As defined by the American Psychiatric Association (APA) Diagnostic and Statistical Manual for Mental Disorders, fifth edition (DSM-5), cannabis substance use disorder is classified by the presence of two or more criteria occurring within a 12-month period (APA, 2013). Many of the nationally representative monitoring systems have not transitioned to this current definition and instead utilize substance use dependence and abuse classification guidelines from the Diagnostic Statistical Manual for Mental Disorders, fourth edition (DSM-IV). Similarities and discrepancies between these categorizations are displayed in Table 2. As is apparent, the newer cannabis use disorder definition incorporates all of the previous cannabis dependence use criterion and the majority of the abuse criterion with one addition, the presence of craving or strong urges to use the substance (BehaveNet, 2016).

Due to the recent changes in diagnostic criterion, the available data collapses cannabis use and abuse categories in order to identify the prevalence of cannabis use disorder. Although current cannabis use has increased, the prevalence of cannabis use disorders among those aged 12 and older has decreased from 1.8% in 2002 to 1.6% in 2014 (CBHSQ, 2015). For young adults (aged 18-25), cannabis use disorder decreased from 6.0% in 2004 to 4.9% in 2014 (CBHSQ, 2015). Among US adults, cannabis use disorder slightly increased from 0.8% in 2002 to 0.9% in 2014 (CBHSQ, 2015). Taken together, national data across multiple groups suggest that overall cannabis use is increasing moderately while the prevalence of cannabis use disorders has experienced little change over the same time period. These discrepancies in cannabis use and disorder incidence may be due to changes in substance disorder criteria as well as lagged effects in disorder development. Continued surveillance is essential to better understand these trends.

Table 2. Comparison of Substance Use Disorder, Substance Use Dependence, and Abuse Criterion by DSM Edition

DSM-5 (APA, 2013) Cannabis use disorder	DSM-IV-TR (BehaveNet, 2016) Substance (marijuana) use dependence	DSM-IV-TR (BehaveNet, 2016) Substance (marijuana) abuse
A problematic pattern of cannabis use leading to clinically significant impairment or distress, as manifested by at least **two** of the following, occurring within a 12-month period:	A maladaptive pattern of substance use, leading to clinically significant impairment or distress, as manifested by **three** (or more) of the following, occurring at any time in the same 12-month period:	A maladaptive pattern of substance use leading to clinically significant impairment or distress, as manifested by **one** (or more) of the following, occurring within a 12-month period
Tolerance, as defined by either of the following: - A need for markedly increased amounts of cannabis to achieve intoxication or desired effect. - Markedly diminished effect with continued use of the same amount of cannabis.	Tolerance, as defined by either of the following: - a need for markedly increased amounts of the substance to achieve intoxication or desired effect - markedly diminished effect with continued use of the same amount of the substance	NA
Withdrawal, as manifested by either of the following: -The characteristic withdrawal syndrome for cannabis. -Cannabis (or a closely related substance) is taken to relieve or avoid withdrawal symptoms.	Withdrawal, as manifested by either of the following: - the characteristic withdrawal syndrome for the substance - the same (or a closely related) substance is taken to relieve or avoid withdrawal symptoms	NA
A great deal of time is spent in activities necessary to obtain cannabis, use cannabis, or recover from its effects.	A great deal of time is spent in activities necessary to obtain the substance, use the substance, or recover from its effects	NA
There is a persistent desire or unsuccessful efforts to cut down or control cannabis use.	There is a persistent desire or unsuccessful efforts to cut down or control substance use	NA
Cannabis is often taken in larger amounts or over a longer period than was intended.	The substance is often taken in larger amounts or over a longer period than was intended	NA
Continued cannabis use despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of cannabis.	The substance use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by the substance	NA
Important social, occupational, or recreational activities are given up/reduced because of cannabis use.	Important social, occupational, or recreational activities are given up or reduced because of substance use	NA
Recurrent cannabis use in situations in which it is physically hazardous.	NA	Recurrent substance use in situations in which it is physically hazardous
Cannabis use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by cannabis.	NA	Continued substance use despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of the substance
Recurrent cannabis use resulting in a failure to fulfill major role obligations at work, school, or home.	NA	Recurrent substance use resulting in a failure to fulfill major role obligations at work, school, or home.
NA	NA	Recurrent substance-related legal problems (e.g., arrests for substance-related disorderly conduct)
Craving, or a strong desire or urge to use cannabis.	NA	NA

Note: NA indicates non-applicable meaning there is no equivalent criteria within this edition

Alternative Cannabis Consumption and Production Methods

Most national assessments (e.g., National Survey on Drug Use and Health [NSDUH], Monitoring the Future [MTF], & Youth Risk Behavior Survey [YRBS]) typically evaluate cannabis use with broad questions which capture lifetime use, current use (e.g., past month), and age of initiation. Unfortunately, these general use questions do not capture the wide array of administration methods or forms available. Forms of cannabis include dried (i.e., cannabis in its original form), concentrates (e.g., butane hash oil, kief, shatter, wax, and rosin), and cooked cannabis (which includes tinctures, sprays, and cannabutter, for example). Concentrates, commonly known as dabs, kief, (butane) hash oil, wax, budder, and shatter, are products with elevated THC levels compared to traditional dried cannabis (Loflin & Earleywine, 2014; Raber, Elzinga, & Kaplan, 2015).

Forms of cannabis can be consumed alone or in combination via a variety of methods of administration. Methods of cannabis administration include smoking or inhaling with joints (cannabis wrapped in a cigarette rolling paper; often but not always containing tobacco) and blunts (cannabis wrapped in tobacco leaves or hollowed cigars; often but not always containing tobacco) as well as use of bowls/pipes, bongs, hot knives, rigs, vaporizers, and edibles (Schauer, King, Bunnell, Promoff, & McAfee, 2016). Bowls and pipes are devices most often made of glass and made in a variety of shapes and sizes (see **Figure 1A**). Cannabis is placed in the concave "head" of the bowl/pipe where it is combusted by a lighter or other heat source. Bongs are devices made from glass, plastic or other materials that are composed of a concave orifice (typically removable) where cannabis is placed and heated but with the addition of a bowl at the bottom of the device where water is placed (similar to hookah/waterpipe devices; see **Figure 1A**;

Kelly, 2005). Hot knives are commonly used with concentrated cannabis. Two metal knives are heated with a blowtorch or a kitchen stove and a small amount of cannabis concentrate is placed on the heated knife blades (Urbanremo, 2015). The cannabis is then inhaled in one of two ways: 1) the knives are situated near the user's mouth and the user inhales or 2) the knives are placed under a water bottle with a cut bottom and the user inhales through the top of the water bottle. Rigs are devices similar to bongs in which a glass, ceramic, or titanium rod (called a "nail") is heated with a blowtorch or an electronic heating source (see **Figure 2**; Raber et al., 2015). Rigs are used exclusively with cannabis concentrates which immediately aerosolize upon contact with the nail, and the emissions are inhaled through the top of the device, similar to a bong (Loflin & Earleywine, 2014; Miller et al., 2016; Raber et al., 2015). Vaporizers are relatively modern electronic devices commonly known as electronic cigarettes (e-cigarettes) or e-hookahs (**Figure 1B**; Breland et al., 2016). More commonly, these devices are used with nicotine-containing liquid (Breland et al., 2016); however, many devices are also manufactured specifically for use with dried cannabis flowers, cannabis concentrates, or cannabis containing liquid/oil (e.g. Pax, Atmos vaporizers, Quick draw; Figure 1B; D. C. Lee, Crosier, Borodovsky, Sargent, & Budney, 2016). These devices contain a power source (battery), heating element, or atomizer that, when activated, warms to a temperature that produces an aerosol to be inhaled (Breland et al., 2016; Giroud et al., 2015; D. C. Lee et al., 2016). Another method of cannabis consumption is ingestion of foods or drinks made with cannabis, commonly called "edibles" (Vandrey et al., 2015). Tinctures are ingestible mixtures of cannabis and high-proof alcohol. The medical cannabis community commonly use tinctures, mixing them with food, drinks, or placing small doses directly into their mouths (Schnelle, Grotenhermen, Reif, & Gorter, 1999).

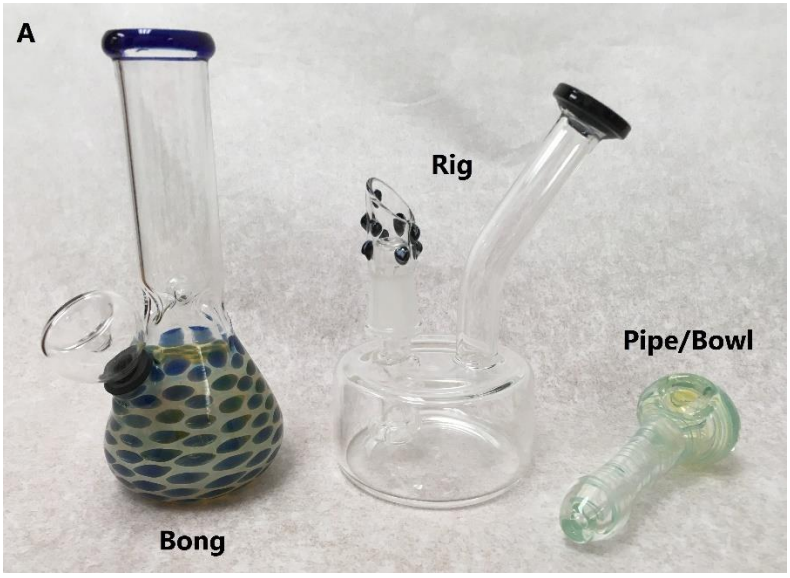

Figure 1. Devices for cannabis consumption. Panel A displays typical glass devices including a bong, rig, and bowl/pipe. Panel B displays electronic devices including a dry material vaporizer and an electronic cigarette where cannabis-containing liquid would be loaded.

Figure 2. A cannabis concentrate rig. A cannabis concentrate rig typically includes a dome (which helps contain the cannabis emissions) and a nail (where the concentrate preparation is placed).

Methods of cannabis production and product development have matured with the passing of medical and recreational cannabis laws. Traditionally, cannabis grows outdoors in soil; however, other forms of production such as indoor hydroponics are used to increase yields and decrease production time (Knight et al., 2010). Hydroponics is a method of growing cannabis, which does not use soil, but instead uses nutrient-rich water to grow plants. According to informal reports, indoor growing systems provide the most control over the growing environment with the use of LED or high-intensity discharge lights, exhaust fans, and temperature, humidity, and carbon dioxide regulation (Danko, 2016). After cultivation, the dried cannabis is kept in its original form or made into different forms such as concentrates and edibles. Growing cannabis often involves propagation and crossbreeding in order to create new species of cannabis (Beutler, 1978). Due to the legalitiy of cannabis, the rapid growth of the cannabis industry, and the development of new production technologies, the regulation and monitoring of cannabis production is extremely difficult.

Limited research exists on the prevalence of specific methods or combinations of methods of cannabis consumption, but combustion-based methods appear to be the most commonly used by recreational cannabis users (Hindocha, Freeman, Ferris, Lynskey, & Winstock, 2016; J. R. Hughes et al., 2014; Schauer, King, et al., 2016). Baseline data from a study of US adult daily cannabis users during 2010-2012 showed that more than half reported weekly usual use of joints (53%), blunts (51%), pipes (55%), or bongs (32%) with fewer individuals endorsing use of vaporizers (6%; J. R. Hughes et al., 2014). Within this same study, participants' daily use of cannabis, including consumption method, was monitored using an interactive voice response system; these data indicated that over 3 months, 59% used at least

three modes of cannabis consumption (joint, blunt, and pipe/bong/vaporizer) and fewer than 3% used only joints or only blunts. Pipe/bong use was the most prevalent method endorsed during daily monitoring (49% of days monitored) followed by blunts (33%) and joints (16%; J. R. Hughes et al., 2014). A more recent nationally representative sample of US adults collected in 2014 indicated that among past 30-day users, the most common methods of use were pipe/bowl (50%), joint (49%), bong/water pipe/hookah (22%), and blunt/cigar (20%) with fewer individuals endorsing use of edibles (16%), vaporizer/electronic devices (8%), and cannabis in "other ways" (5%; Schauer, King, et al., 2016). Most users endorsed one method of use (59%) but almost 20% endorsed three or more; importantly results from this study did not distinguish which methods were most commonly used exclusively or in combination (Schauer, King, et al., 2016).

An online global (Europe, Australasia, and US/Americas) survey performed in 2013 including over 70,000 participants examined past year cannabis use characteristics by route of administration focusing specifically on those consumed in combination with tobacco (i.e., joint with tobacco, pipe with tobacco) versus those without tobacco (i.e., joint without tobacco, pipe without tobacco, vaporizer; Hindocha et al., 2016). Overall results indicated tobacco-containing administration methods (i.e., joints with tobacco) were endorsed more highly (66%) by past year users, but the most common non-tobacco-containing method was pipe without tobacco (12%). US-specific results revealed an alternative pattern with non-tobacco methods emerging as the most common (92%) with the highest endorsement for pipe without tobacco (48%; Hindocha et al., 2016). Taken together, these data support the assertion that combustion-based methods are

likely the most common among US cannabis users, but importantly new trends, policies, and available methods of use are likely to influence these patterns of consumption.

Inhalation and oral methods of administration may be increasing in some populations. The Association for Cannabis and Medicine (Cologne, Germany) administered an anonymous survey in Germany, Austria, and Switzerland in 1999 to examine use patterns of self-medicating cannabis users (Schnelle et al., 1999). Across their lifetime, almost half of the sample (49%) had used inhalation methods of administration, 14% had used oral methods, and 37% had used both inhalation and oral methods (Schnelle et al., 1999). The same researchers administered the survey again in 2001 in Germany and Switzerland (Grotenhermen & Schnelle, 2003). Over half of participants (56%) inhaled cannabis products while 17% consumed cannabis orally and 23% used both inhalation and oral methods (Grotenhermen & Schnelle, 2003). These results indicate that, in certain populations, the individual use of inhalation and oral methods of cannabis administration may have increased over time while the dual use of oral and inhalation methods decreased.

The use of cannabis concentrates via rig or vaporizer specifically appears to be one of the newest consumption methods to gain popularity and is coupled with concerning reports of abuse-related side effects associated with use. A Google Trends analysis between 2004-2015 which tracked the frequency of searches that included “dabbing” (i.e., concentrate use) and other similar terms indicated that prior to 2013 cannabis smoking and edible terms were searched more often than “dabbing” (Zhang, Zheng, Zeng, & Leischow, 2016). However, by 2015, “dabbing” searches were 28% higher than cannabis smoking terms and 58% higher than edible search terms (Zhang et al., 2016). An online US study conducted in 2014 included 357 adults who had used

concentrates in their lifetime (Loflin & Earleywine, 2014). Results showed that approximately one third (32%) of participants who had tried a vaporizer with concentrates preferred using a vaporizer instead of a hash oil rig. Data also indicated that the most endorsed reasons for using concentrates were that participants needed fewer doses to receive the same effect, the "high" was stronger, and the "high" felt subjectively different (Loflin & Earleywine, 2014). This data serves as an indication of the rapidly growing popularity of cannabis concentrates.

Vaporizer use in particular appears to be prevalent in US adolescent and young adult populations. Among a 2014 sample of US high school students in Connecticut, 5% had ever used cannabis with a vaporizer (Morean, Kong, Camenga, Cavallo, & Krishnan-Sarin, 2015). When restricted to ever cannabis users, 18% had used cannabis with a vaporizer. The study also measured the type of cannabis product used in vaporizers (i.e., concentrates or dried cannabis). Among those who indicated lifetime cannabis use, 16% had used concentrates in a vaporizer while 23% had used dried cannabis in a vaporizer (Morean et al., 2015). Among a 2013 sample of US high school students in Colorado (assessed prior to implementation of retail marijuana availability), 20% reported past 30-day cannabis use with 85% of users indicating smoking as their usual mode of consumption followed by vaporizing (6%), edibles (5%), and other (4%; R. M. Johnson et al., 2016). Among one sample of US undergraduate students in Arizona, past year cannabis use was reported by 44%, with cannabis vaping at 23%, and over half of past-year cannabis users had tried cannabis vaping in the past year (51%; Jones, Hill, Pardini, & Meier, 2016).

Importantly, vaporizer use for cannabis consumption is not limited to younger age groups. In an online sample of cannabis-using US adults in 2014-2015, 61% of the sample had

ever used a vaporizer to administer cannabis, with most indicating using a vaping pen (45%) or tabletop device (23%) followed by a portable device (15%) and e-cigarette (11%; D. C. Lee et al., 2016). Dual use of smoking and vaping cannabis was reported by 76% of the sample; smoking cannabis was still the most frequently used method and very few individuals reported vaping exclusively (D. C. Lee et al., 2016). An online study conducted in 2013 included 96 adults who used a vaporizer with cannabis (Malouff, Rooke, & Copeland, 2013). The most endorsed reasons for using cannabis with a vaporizer were perceived health benefits, better taste, no smoke smell/discreetness, and users achieve more drug effects with the same amount of cannabis (Malouff et al., 2013)

As presented above, patterns of cannabis consumption in the US are evolving, and while combustion-based methods still may be the most common, engagement in multiple methods is also prevalent. Differential consumption methods may be associated with varying use trajectories, patterns of consumption, psychoactive and health-related effects, and importantly, predictors and correlates of cannabis use. Of the latter, predictors and correlates may be most useful for informing the development of prevention or intervention efforts to reduce the negative consequences associated with cannabis use.

Predictors and Correlates of Cannabis Use

Available data suggests that a wide range of factors are predictive of cannabis use including demographics (i.e., race/ethnicity, gender), harm perceptions regarding cannabis use, and other risk-taking behaviors such as tobacco and alcohol use. Importantly, much of the work regarding predictive factors of cannabis use includes populations/settings outside of the US so consideration of the population studied is key when interpreting findings (Haug, Nunez, Becker,

Gmel, & Schaub, 2014; Korhonen et al., 2010; McGee, Williams, Poulton, & Moffitt, 2000; Mills, Kisely, Alati, Strathearn, & Najman, 2016). Patterns of predictive factors may differ in US populations relative to other international settings due to the differences in cannabis policy environments.

In terms of demographics, the literature on race/ethnicity correlates among cannabis users is heterogeneous. Among one sample of young adults, identifying as American Indian/Alaskan Native was positively associated with past year cannabis use (R. M. Johnson et al., 2015); however, other evidence suggested that cannabis users are more likely to identify as White (Bell, Wechsler, & Johnston, 1997; R. M. Johnson et al., 2016; Kaynak et al., 2013) or Asian (R. M. Johnson et al., 2016). For gender, the literature is more consistent with cannabis use being strongly associated with identifying as a male (Bell et al., 1997; Coffey, Lynskey, Wolfe, & Patton, 2000; R. M. Johnson et al., 2016; D. C. Lee et al., 2016). More recent work suggests that demographic correlates may differ based on method of cannabis use. In one examination, blunt-only users were more likely to be African American compared to non-blunt cannabis users (A. Cohn, Johnson, Ehlke, & Villanti, 2016). Men are also more likely to use cannabis with a vaporizer (Jones et al., 2016; D. C. Lee et al., 2016; Morean et al., 2015) which is consistent with data from tobacco literature regarding electronic cigarette use (McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2015; Schoenborn & Gindi, 2015). These data support inquiry into understanding the demographic profiles of cannabis users by consumption method endorsed.

Harm perceptions regarding cannabis is another class of factors that has strong associations with use. Among a nationally representative sample of US adults in 2012 and 2014, approximately 29% perceived a great risk of harm from monthly cannabis use (A. Hughes,

Lipari, & Williams, 2016). Areas of the country with highest levels of use were more likely to perceive lower risks of harm from monthly cannabis use (A. Hughes et al., 2016). Among a sample of 725 US young adults in 2007, non-cannabis users reported higher risk of future academic consequences compared to cannabis users (71% vs. 20%; Kilmer, Hunt, Lee, & Neighbors, 2007). In the same study, non-cannabis users also perceived higher risk of social consequences compared to cannabis users (55% vs. 9%; Kilmer et al., 2007). Among a sample of young adults in Australia in 2006, lifetime cannabis users perceived cannabis as less risky compared to participants who had never used cannabis (O'Callaghan, Reid, & Copeland, 2006). Lifetime cannabis users' perceived risk was lower on six dimensions: feeling sick after using, using other drugs, having accidents while under the influence of cannabis, legal consequences, physical health, and dependence problems (O'Callaghan et al., 2006). These data indicate that perceptions of lower health, social, and academic risks of cannabis use are associated with cannabis use.

A range of other risky behaviors are also associated with cannabis use. Early initiation of cigarette smoking (at age 12 or earlier) is highly predictive of subsequent cannabis use during adolescence (Korhonen et al., 2010). Tobacco and alcohol use also predict cannabis use and dependence in young adulthood (Coffey et al., 2000; Mills et al., 2016). Alcohol, nicotine, and cannabis dependence at age 18 are predictors of past-year cannabis use among young adults (Haug et al., 2014; McGee et al., 2000). Cannabis use is also associated with other illicit drug use (Secades-Villa, Garcia-Rodriguez, Jin, Wang, & Blanco, 2015). A study using the Domain-Specific Risk-Taking scale found that young adult cannabis users were more likely to exhibit social (e.g., disagreeing with a friend), health/safety (e.g., engaging in unprotected sex), and

ethical risks (e.g., stealing) compared to non-cannabis users (Gilman, Calderon, Curran, & Evins, 2015). Indices of high impulsivity/sensation seeking also are predictive of past year cannabis use and cannabis dependence in young adulthood (Haug et al., 2014; Kaynak et al., 2013; McGee et al., 2000). As indicated, engagement in other risky behaviors including alcohol and tobacco use, along with certain race/ethnicity, gender, and harm perception profiles are predictive of general cannabis use. Further, some literature indicates there are differential patterns of predictors and correlates depending on methods of cannabis use.

Few studies have investigated predictors or correlates of alternative forms of cannabis consumption such as vaporizer, concentrate, edible, and blunt use. Among those available, predictors of vaporizer use are cannabis initiation at a young age (D. C. Lee et al., 2016), more frequent (daily) cannabis use (D. C. Lee et al., 2016), high socioeconomic status (Jones et al., 2016), higher perceived health (D. C. Lee et al., 2016), lifetime cigarette use (Morean et al., 2015), and using a vaporizer for nicotine products (Jones et al., 2016; D. C. Lee et al., 2016). Among one large online sample of cannabis users in the US, ever cannabis vaporizer users indicated positive perceptions of vaping cannabis in terms of "health," "taste," "high," and "satisfaction" (D. C. Lee et al., 2016). One qualitative study published in 2016 showed that among US youth aged 15-17, users who preferred edibles were more likely to endorse concerns about smoking cannabis (Friese, Slater, Annechino, & Battle, 2016). Interestingly, edible users in this sample also cited specific risks associated with edible use including edible-induced deaths, risks of the intense edible "high," and unclear strength/content of edible products. This same study suggested that edible use was perceived as more prevalent among females and more accepted by females due to lack of smell or lower risk of discovery by adults (Friese et al.,

2016). One study examined correlates of blunt use and non-blunt cannabis use among US adults using data from the 2013 NSDUH (A. Cohn et al., 2016). Results indicated blunt users and non-blunt cannabis users had similar associations (more likely to be Black, young, male, and used other substances in the past month; however, non-blunt cannabis users had weaker associations with these variables than blunt users.

Predictors and correlates of endorsing multiple consumption cannabis methods (i.e., poly-use) or particular patterns of cannabis use (i.e., vaporizers and rigs or vaporizers-only) have not been examined extensively in the literature. This lack of knowledge in combination with rapidly changing device types and technology all challenge the categorization and understanding of cannabis users and patterns of use. Importantly, there are statistical techniques that are optimized for identifying latent sub-groups of populations, which may be best suited for addressing this challenge.

Methods to Understand Patterns and Correlates of Cannabis Consumption: Latent Class Analysis

Among many statistical techniques used to understand drug-taking behavior, latent class analysis (LCA) has emerged as an advantageous person-centered approach to classify patterns of substance use (Evans-Polce, Lanza, & Maggs, 2016; Haardorfer et al., 2016; Harrell, Naqvi, Plunk, Ji, & Martins, 2016; Nasim, Blank, Cobb, & Eissenberg, 2012; Nasim et al., 2016; Tzilos, Reddy, Caviness, Anderson, & Stein, 2016). LCA groups individuals into "latent" (i.e., unobserved) classes based on their patterns of responding on indicator variables (i.e., selected variables relevant to the research question of interest; McCutcheon, 1987). LCA has been used among adolescent (Harrell et al., 2016; Nasim et al., 2012) and young adult populations (Evans-

Polce et al., 2016; Haardorfer et al., 2016; Nasim et al., 2016; Tzilos et al., 2016) to understand patterns of tobacco use, cannabis/alcohol, as well as other illicit substances (Haardorfer et al., 2016). One advantage is the use of LCA in combination with more traditional regression analyses to examine correlates of class membership. This combination of statistical techniques allows for the exploration of the differential characteristics of sub-groups identified (Pearson, Bravo, Conner, & Marijuana Outcomes Study, 2017).

LCA can be used to examine latent patterns of substance use behavior among specific drug classes such as tobacco products. A national sample of US adolescent cigarette smokers was categorized using indicator variables that included measures of cigarette smoking frequency and intensity, lifetime smoking status, smoking persistence, and past 30-day alternative tobacco use (smokeless tobacco, cigars, bidi, clove cigarettes; Nasim et al., 2012). Each of the six latent classes predicted by the model (class membership prevalence ranged from 55-33%) was defined by unique patterns of cigarette and alternative tobacco product use: Class 1 (non-daily, light smokers), Class 2 (light smokers), Class 3 (light smokers who use alternative tobacco products), Class 4 (intermittent smokers), Class 5 (daily smokers), and Class 6 (daily smokers who use alternative tobacco products). Multinomial regression was used to examine demographic and other smoking-related covariates (i.e., nicotine dependence) that differed between classes. Findings suggested that smokers who engaged in alternative tobacco product use (Classes 3 and 6) exhibited higher nicotine dependence symptomology, consistent with a greater risk profile. These data highlighted the variability in tobacco product consumption among youth and the importance of alternative tobacco product assessment and inclusion in tobacco prevention interventions.

LCA has also been used to understand latent poly-substance use patterns. In a large regional sample of US college students, indicators were selected to capture tobacco use prevalence (frequency of past 4-month and past 30-day use for cigarettes, little cigars/cigarillos, smokeless tobacco, e-cigarettes, and hookah), cannabis use, and alcohol use (Haardorfer et al., 2016). Two sets of LCA models were developed to divide individuals into classes based on their substance use over the past 4 months and past 30 days. Both LCA models resulted in five distinct classes with differing class membership rates: Class 1 (abstainers), Class 2 (alcohol-only), Class 3 (light poly-tobacco users), Class 4 (heavy poly-tobacco users), and Class 5 (little cigar/cigarillo-hookah-marijuana co-users; Haardorfer et al., 2016). Multinomial regression analyses were used to identify demographic, perception-related, and social factor correlates that differed by class membership. Findings revealed important variations in these associations (e.g., light poly-tobacco users were more likely to have parents that used tobacco but less likely to have friends who used tobacco) that were informative for prevention efforts.

LCA may be particularly useful for identifying sub-groups of cannabis users that differ by cannabis use behaviors. Available data indicate that cannabis users, as a whole, have lower harm perceptions (A. Hughes et al., 2016; Kilmer et al., 2007; O'Callaghan et al., 2006) and exhibit risky behaviors (Badiani et al., 2015; Gilman et al., 2015; Secades-Villa et al., 2015) but also are characterized by heterogeneous use patterns (Hindocha et al., 2016; Loflin & Earleywine, 2014; Schauer, King, et al., 2016). Therefore, there may be sub-groups within the larger population of cannabis users which may be best elucidated using LCA techniques. Considering the rapid evolution of cannabis consumption methods and US state-level polices

regarding medicinal and recreational use, this information gap will be critical to assess in terms of understanding the changing population of cannabis users in the US.

History of Cannabis Policy in the US

Like many drugs, cannabis and policy regarding its use has experienced dramatic shifts in political and public opinion since its introduction to modern society. The first record of cannabis use was for medicinal purposes by the ancient Chinese in 2700 BC (M. A. Lee, 2012). Originally, cannabis was used in medicinal teas as a remedy for a variety of ailments including gout, malaria, and constipation. In the 1800s, cannabis was still widely used to treat ailments (M. A. Lee, 2012). By the late 1800's oral ingestion methods were widely switched to smoking (combustion-based; M. A. Lee, 2012). By the 1930s, 24 US states had banned cannabis.

In 1937, the first US law that indirectly banned the production, possession, and usage of cannabis, The Marihuana Tax Act, was passed and created a soaring tax on cannabis (M. A. Lee, 2012). By this time, cannabis use had decreased for medicinal purposes and been replaced with modern-age medicines like aspirin. However, recreational cannabis use still continued (M. A. Lee, 2012). In the 1950s, the US federal government prioritized the restriction of drug use with the Boggs Amendment in 1951 and the Narcotics Control Act of 1956, which both increased penalties for violating drug laws including those regarding cannabis.

In 1970, the Marihuana Tax Act of 1937 was deemed unconstitutional and was replaced by the Controlled Substances Act (CSA; M. A. Lee, 2012). The CSA, initially passed in 1970, was intended by the US Congress to further regulate cannabis and other substances by addressing multiple points including the manufacture, possession, and distribution of substances (FDA, 2009). Since 1970, nine amendments to the CSA have been passed to further regulate other drugs

of abuse (e.g., steroids and psychotropic drugs), chemical precursors, and structurally similar drugs (FDA, 2009). The CSA also created a five-tiered classification system to rank the "potential for abuse" for each substance. According to the CSA, Schedule I substances have a high potential for abuse, no medical uses, and are not safe to use under medical supervision, while Schedule V substances have a low potential for abuse. The classification system categorizes natural cannabis as a Schedule I drug in the US; although synthetic forms of THC (i.e., dronabinol) are classified as Schedule III. The federal penalty for a first offense with possession of cannabis is a fine no less than $1,000 and up to 1 year in prison (Yeh, 2015). However, these penalties vary by state. States with decriminalized laws have minor penalties while other states with strict cannabis laws have major penalties (up to the federal level).

Although cannabis remains illegal on a federal level, many states have opted to create new laws regarding cannabis. In 1996, California was the first state to legalize cannabis for medicinal purposes (Hanson, 2016). During the next twenty years, 28 more states and Washington, DC followed California's lead to legalize cannabis medicinally (Hanson, 2016). Although medicinal cannabis laws between states are heterogeneous; generally, the laws legally constitute the possession of a certain amount of cannabis and the cultivation of a specific number of plants only if the consumer has a medical condition that allows for the use of cannabis (see **Table 3** for a summary by state). In 2012, Colorado became the first state to legalize both recreational and medicinal cannabis, followed by Washington one month later. Both Oregon and Alaska legalized cannabis for recreational and medicinal purposes in 2014. In 2016, California, Maine, Massachusetts, and Nevada legalized recreational cannabis (NPR, 2016). Recreational cannabis laws vary across states by possession amount, number of plants allowed for cultivation,

Table 3. US States with Legalized Medical and/or Recreational Cannabis Laws

US State	Cannabis products available for medical use	Cannabis products available for recreational use	Recreational use policy details (Ballotpedia, 2016; NORML, 2016)
Alaska	Yes	Yes	1 oz. possession & grow 6 plants
Arizona	Yes	No	--
Arkansas	Yes	No	--
California	Yes	Yes	1 oz. possession, grow 6 plants, & 8 g concentrate possession
Colorado	Yes	Yes	1 oz. possession, grow 6 plants, & 1 oz. concentrates
Connecticut	Yes	No	--
Delaware	Yes	No	--
Washington, DC	Yes	Yes	2 oz. possession & grow 6 plants
Florida	Yes	No	--
Hawaii	Yes	No	--
Illinois	Yes	No	--
Louisiana	Yes	No	--
Maine	Yes	Yes	2.5 oz. possession & grow 6 plants
Maryland	Yes	No	--
Massachusetts	Yes	Yes	1 oz. possession & grow 6 plants
Michigan	Yes	No	--
Minnesota	Yes	No	--
Montana	Yes	No	--
Nevada	Yes	Yes	1 oz. possession, grow 6 plants, & 1/8th oz. concentrates
New Hampshire	Yes	No	--
New Jersey	Yes	No	--
New Mexico	Yes	No	--
New York	Yes	No	--
North Dakota	Yes	No	--
Ohio	Yes	No	--
Oregon	Yes	Yes	1 oz. possession, grow 4 plants, 72 oz. of liquid concentrates, 16 oz. of solid concentrates, & 1 oz. of concentrate extract
Pennsylvania	Yes	No	--
Rhode Island	Yes	No	--
Vermont	Yes	No	--
Washington	Yes	Yes	1 oz possession, 72 oz. of liquid concentrates, 16 oz. of solid concentrates, & 7 g of concentrate extract.

Note. Cannabis products include dried plant material.

and the legality of concentrates; however, all recreational cannabis users must be 21 years of age (see **Table 3**). Importantly, although many states and territories have relatively ignored the stipulations of the CSA, cannabis is still considered federally illegal in the US. These changes in cannabis policy warrant investigation in order to reduce the potential harms of cannabis legalization on youth and young adults (Choo & Emery, 2016; Dirisu, Shickle, & Elsey, 2016).

Methods to Evaluate Cannabis Policy Change

Measures of trends in drug use are among the most common means to measure the effects of policy changes. One study, conducted between 1991 and 2001, paired states with and without medical cannabis laws and compared past month adolescent cannabis use rates (Choo et al., 2014). No significant differences were found in adolescent cannabis use between states with and without medical cannabis laws (Choo et al., 2014). However, another more recent study conducted between 2002 and 2011 using data from NSDUH determined that adolescent cannabis use rose after the implementation of medical cannabis laws (Stolzenberg, D'Alessio, & Dariano, 2016). Results from another study that examined the effects of international drug policies in a sample of over 170,0000 adolescents in 38 countries across three time points (2001-2010) determined that adolescents were more likely to report lifetime, past year, and regular cannabis use in legalized policy environments relative to an illegalized policy environment (Shi, Lenzi, & An, 2015). A study using longitudinal data in 1991-2011 from the YRBS examined the influence of medical cannabis laws on cannabis use among adolescents (J. Johnson, Hodgkin, & Harris, 2017). After controlling for state, year, and demographic variables, data indicated that although cannabis use was higher in states with medical cannabis laws, there was no increase in past 30-

day cannabis use or past 30-day heavy cannabis use due to policy changes in states with medical cannabis laws (J. Johnson et al., 2017). Therefore, researchers indicated that the difference in cannabis use patterns was likely due to differential social norms in each state, not medical cannabis laws (J. Johnson et al., 2017). These data illustrate the utility of prospectively monitoring changes in drug use before and after a policy is implemented as well as collecting other measures (i.e., social norm indices) that may be associated with changes in drug use.

There is strong evidence that effects of drug policy on drug use behavior may be influenced by harm perceptions and social norms (L. D. Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2016). The MTF study examines 12th graders' perceived risk, disapproval, and availability of cannabis as well as cannabis use behavior over time (L. D. Johnston et al., 2016). Between the 1970s and 1990s, perceived risk of cannabis decreased while cannabis use increased (L. D. Johnston et al., 2016). This trend suggests that increasing perceived risk may reduce rates of cannabis use, but more recent data highlights the complex interplay of these factors. From 2005 to 2015, the percentage of 12th graders who reported a "great risk" in regular cannabis use declined from 58% to 32% without a corresponding increase in cannabis use (L. D. Johnston et al., 2016). Other data from the NSDUH indicated that the relationship between harm perceptions and cannabis use patterns among people aged 12 and older (i.e., lower perceived harm coupled with lower use) was still evident from 2012 to 2014 (A. Hughes et al., 2016). This decline in perceived risk among both youth and adult populations could be the result of cannabis policy changes throughout the US. Cannabis was prohibited originally in the US due to its purported increased harm potential to users. Due to the relaxation of medical and recreational cannabis laws, youth now may interpret that cannabis is safe to use (Dirisu et al., 2016). Data from the

MTF study also indicated that although personal disapproval of regular cannabis use in 2015 remained high for 12th graders (71%), this rate of disapproval had decreased since 2007 (83%). In addition, the percentage of 12th graders who reported that cannabis is "fairly easy" or "very easy" to obtain has remained between 80% and 90% since the beginning of the MTF study in 1975. In 2015, approximately 80% of 12th graders reported that cannabis was easily attainable. Decreases in perceived risk and disapproval of cannabis use and increases in access to cannabis in response to cannabis policy changes could contribute to future changes in cannabis use patterns (L. D. Johnston et al., 2016).

Although useful, measuring drug use patterns and associated factors like harm perceptions and disapproval before and after a policy change is not always viable (such as the case of a future or proposed policy change). In addition, pre-post designs cannot be used to examine unintended effects prior to policy implementation or when developing cannabis policies that have not been implemented in other environments. For example, pre-post studies do not illustrate what effects would occur following legalization of cannabis in a state with long-standing restrictions on medical and recreational use (e.g., Virginia or Wisconsin). While these environments may share some similarities to other US states where cannabis legalization policy has been implemented (e.g., Colorado or Washington), important geographical and population differences may result in differential outcomes and risks to certain populations like youth or young adults.

Simulation modeling provides one option to help predict the impact of future or hypothetical health policies, but this approach typically requires longitudinal data sources as a foundation (Cobb et al., 2015; Levy, Bauer, & Lee, 2006; Levy et al., 2011). Choice

experiments, which are primarily used in economics literature, could also be used to evaluate potential policy changes; however, these methods incorporate a price or "willingness to pay" framework which would add a price dynamic into the study. Prices for cannabis tend to fluctuate depending on the state, the specific laws in that state or locality, and the time of year. Choice experiments would add a price confound into the methods (Barnes et al., 2013; Ginon, Chabanet, Combris, & Issanchou, 2014; Olesen, Alfnes, Bensze Røra, & Kolstad, 2010). Importantly, the use of experimental and cross-sectional designs, often driven by behavior change theories, can provide an additional alternative to understand the impact of potential policy changes related to health behaviors (Darmon, Lacroix, Muller, & Ruffieux, 2014; Epstein et al., 2015; Pesko, Kenkel, Wang, & Hughes, 2016; Wackowski, Manderski, & Delnevo, 2014). These types of studies typically compare alterations of a policy environment relative to the "status quo" or current policy environment to determine the hypothetical impact on outcomes of interest including intentions to use a drug (e.g.., tobacco, cannabis) or engage in a behavior (e.g., purchase food/calories). Many studies have shown a consistent relationship between intentions to use cannabis and the actual use of cannabis (D'Amico, Miles, & Tucker, 2015; L. D. Johnston et al., 2016; Kilmer et al., 2007; Lopez-Quintero & Neumark, 2010). Using intentions as a primary outcome is supported by several theories of behavior change including the Theory of Planned Behavior (Ajzen, 1991).

As described above, methods to evaluate cannabis policy change are dominated by long-term longitudinal approaches that measure cannabis use behavior and proximal outcomes such as cannabis harm perceptions, disapproval rates, and availability perceptions. In the absence of such data or to address questions regarding the potential effects of new or hypothetical cannabis

policy in untested environments, alternative methods must be considered. Experimental designs using a behavior change theory approach provide one such option.

Predicting cannabis use: The Theory of Planned Behavior. The Theory of Planned Behavior (TPB) is a suitable framework for assessing cannabis use and the antecedents of use (Ajzen, 1991; Conner & McMillan, 1999). The TPB reveals motivations and beliefs about a behavior (Glanz, 2015). The TPB incorporates three main factors that influence intentions to act on a behavior and consequently, the behavior itself (Ajzen, 1991). The three factors that influence intentions are 1) attitudes about the behavior, 2) subjective norms, and 3) perceived behavioral control. Attitudes are positive or negative beliefs about a behavior. Subjective norms are the perceived pressures to perform a behavior. Two distinct categories fall under subjective norms: injunctive/normative and descriptive norms. Injunctive norms are the pressures one feels from others to engage in a behavior (i.e., "do others think you should use cannabis?"). Descriptive norms are perceived beliefs about the engagement of others in the behavior (i.e., "do you think other people use cannabis?"). Perceived behavioral control is how easy or difficult it is for one to perform the behavior. Self-efficacy is the belief one has in their ability to complete a behavior. These three components – attitudes, subjective norms, and perceived behavioral control – contribute to intentions to perform a behavior. Ajzen postulated that intentions to perform a behavior is the closest antecedent to actual behavior performance (1991). A hypothetical cannabis policy environment may influence attitudes, subjective norms, and perceived behavioral control, as well as intentions to perform a behavior.

Due to the hypothetical nature of evaluating changes in a not-yet implemented cannabis policy environment, it is challenging to measure actual behavior performed. Therefore,

examining intentions to perform a behavior, in this case, intention to use cannabis, as well as associated influential factors (attitudes, subjective norms, and perceived behavioral control) provide the optimal tools in which to test the impact of a future cannabis policy change within an existing policy environment.

Statement of the Problem

Cannabis is a drug class that can be used in a variety of ways through different types of administration with little data available regarding patterns and profiles of cannabis use by consumption method. This information may have important implications for understanding cannabis user populations and informing cannabis prevention and intervention efforts. The US cannabis policy environment is rapidly changing with many states legalizing cannabis for medicinal use and several states legalizing recreational cannabis despite the US federal government's illegal stance on cannabis. These changes may affect the methods in which cannabis is consumed and the types of individuals who consume cannabis. Understanding the influence of cannabis policy changes (i.e., increased legalization) is needed particularly for unique and untested environments that may respond differentially compared to those where cannabis policy has already been implemented and/or longitudinal data is available. Assessment of these policy-related outcomes using an experimentally-based design can inform regulators and potentially limit the harms of future cannabis policy on at-risk populations such as young adults.

The Present Study

This study has three primary aims: 1) to assess what methods and patterns of cannabis consumption are most prevalent among young adults using an LCA approach, 2) to test whether certain patterns of cannabis use are associated with differential demographics, harm perceptions,

and risk taking behaviors, and 3) to determine if hypothetical cannabis policy environments (legal-policy vs. medical-policy vs. illegal-policy) influence attitudes, injunctive norms, perceived behavioral control, and intentions to use cannabis among a young adult population.

Hypothesis 1: The largest latent classes of young adult cannabis users will involve combustion-based methods of cannabis use (i.e., joints, blunts, bongs, and bowls). Evidence from adolescent populations indicates combusted methods are most prevalent (D. C. Lee et al., 2016). We expect that users may engage in multiple methods of cannabis consumption, but combustion-based consumption or a combination of combustion-based methods will be most frequent.

Hypothesis 2: Latent classes composed of primarily combusted cannabis users will significantly differ in their demographics, harm perceptions, and risk-taking behaviors from user classes who primarily use non-combusted forms of cannabis. Combusted cannabis users will more likely be male, White/Caucasian, have lower harm perceptions about cannabis, and have greater risk-taking behaviors relative to those who use non-combusted forms of cannabis.

Hypothesis 3: The legal-policy condition will elicit the highest intentions to use, followed by the medical-policy condition and the illegal-policy condition. Self-reported attitudes towards cannabis will be highest (i.e., more favorable) in the legal-policy condition and lowest in the illegal-policy condition. Injunctive norms regarding cannabis will be highest in the legal-policy condition followed by the medical-policy condition and the illegal-policy condition. Measures of perceived behavioral control and self-efficacy to use cannabis will be highest in the legal-policy condition and lowest in the illegal-policy condition.

Method

Selection of Participants

Approximately 1,500 students from a large (30,000 students) urban university in a Mid-Atlantic US city were potentially eligible to participate in this online cross-sectional survey study based on course enrollment. Eligibility criteria to participate were undergraduate student status, at least 18 years of age, and enrolled in a course where research credit could be earned to satisfy course requirements. Between February 2017 and May 2017, 543 participants enrolled in this study. Of the total participants enrolled, 86 were excluded from analyses due to failure to meet inclusion criteria (n = 3), failing to complete any of the survey beyond consent (n = 24), failing the attention check (n = 18), failing to finish the survey in its entirety (n = 40), and illogical responding (n = 1). The final sample consisted of 457 participants of which 208 (45.5%) met criteria for analysis for Hypothesis 1 (past month cannabis use), 204 (45.5%) met criteria for analysis for Hypothesis 2, and 446 (97.6%) met criteria for analysis for Hypothesis 3.

The enrolled sample met the proposed sample projection of approximately 500 participants which was based on preliminary data from two similarly designed studies of undergraduate students at the same institution performed in Spring 2016 and Fall 2016. These two previous studies estimated past 30-day cannabis use was between 30-50% (personal communication with C. Cobb) resulting in an analytic sample for the LCA (Hypothesis 1) between 150-250 individuals (meeting minimum sample size for LCA which ranges from 100-500; Collins & Wugalter, 1992; Finch & Bronk, 2011; Wurpts & Geiser, 2014). The projected sample size for the LCA was expected to at least allow for logistic regression analyses to examine differences in demographics, harm perceptions, and risk behaviors between the two

largest classes identified. For Hypothesis 3, the entire sample (N ≈ 500) was planned to be utilized, and a power analysis aimed to detect a small to medium effect size of $f = 0.25$ ($\alpha = 0.05$, with at least 6 covariates; power = 0.95) for an analysis of covariance (ANCOVA) determined a minimum sample size of 210 participants (GPower 3.1.9.2). The current study protocol and all associated measures were approved by the Virginia Commonwealth University's Institutional Review Board.

Procedures

The study design was cross-sectional and used only self-report measures, which was executed completely online. Interested individuals reviewed study information via an online study system developed specifically for administering undergraduate research studies (SONA, https://vcu.sona-systems.com). If interested in a particular study, participants "signed up" to gain access to the study-specific weblink. After clicking on the weblink, participants were routed outside of the study system to a secure webpage that hosted the experimental survey (administered via Qualtrics). After reviewing a brief description of the study and expected involvement, participants clicked yes to agree to continue and then confirmed eligibility status (age ≥18 years old and undergraduate student status). Participants who did not meet eligibility requirements were excluded from participation. Following eligibility confirmation, the survey consisted of baseline measures asked of all participants (see **Measures** below) followed by randomization to one of three hypothetical cannabis policy conditions: legal-policy, medical-policy, or illegal-policy (see **Cannabis Policy Conditions** below). At the conclusion of the survey, participants were directed to click a weblink which directed them to a separate survey webpage to leave their name and contact information for crediting purposes (0.5 credits per

person). This practice ensured the survey data were not directly linked with individuals' identifying information. Individuals who did not reach this point in the survey were instructed to email the survey administrators directly to obtain partial credit (0.20 credits).

Measures

All participants completed a survey that consisted of baseline demographic measures, cannabis, alcohol, and tobacco use patterns, tobacco and cannabis harm perceptions, risk-taking behaviors, and baseline intentions to use cannabis followed by randomization to one of three hypothetical cannabis policy conditions (legal-policy, medical-policy, or illegal-policy) where cannabis attitudes, descriptive norms, injunctive norms, perceived behavioral control, self-efficacy, and intentions to use were assessed. One question was included as an attention check, and participants who completed an answer to the attention check were excluded from analysis (n = 18).

Cannabis Policy Conditions. After completing baseline measures, participants were randomly assigned automatically to one of three hypothetical cannabis policy conditions (legal-policy, medical-policy, or illegal-policy) where a condition-specific scenario was presented (See **Table 4** and **Appendix A**). Participants were instructed to complete six measures within the context of the assigned hypothetical cannabis policy condition (i.e., attitudes, descriptive norms, injunctive norms, perceived behavioral control, self-efficacy, and behavioral intentions). In order to ensure participants recalled which policy condition to which they were randomized, a policy condition prompt was shown at the top of each measure (See **Appendix B**).

Table 4. Cannabis Policy Conditions

Item Description	Legal Cannabis Policy Condition	US State Policy Reference (Ballotpedia, 2016; NORML, 2016)	Medical Cannabis Policy Condition	US State Policy Reference	Illegal Cannabis Policy Condition	US State Policy Reference (Ballotpedia, 2016; NORML, 2016)
Instructions	The next several sections will ask you to answer the questions in the context of the situation stated below. Imagine you live in a state where marijuana is **medically** and **recreationally** LEGAL.	NA	The next several sections will ask you to answer the questions in the context of the situation stated below. Imagine you live in a state where marijuana is **medically** LEGAL	NA	The next several sections will ask you to answer the questions in the context of the situation stated below. Imagine you live in a state where marijuana is **medically** and **recreationally** ILLEGAL.	NA
Medical use	Patients with written medical consent may possess up to two ounces of medical marijuana.	Similar to Colorado, Washington, DC, New Hampshire, New Jersey, & Vermont	NA	NA	Marijuana in any form may not be prescribed by any medical professional.	All illegal cannabis states
Age	Use of marijuana is legal for anyone over the age of 21.	All recreational cannabis laws	Anyone with written medical consent may use marijuana for medical purposes.	Similar to Arizona, Illinois, & Maine	Use of marijuana is illegal for anyone of any age.	All illegal cannabis states

Possession and cultivation	Anyone over the age of 21 may possess up to 1 ounce of retail marijuana and may grow up to 6 marijuana plants.	Similar to Alaska, California, & Colorado	Anyone with written medical consent may possess up to 2.5 ounces of medical marijuana. Growing marijuana of any amount may result in criminal prosecution and fines.	Similar to Arizona, Illinois, & Maine	Possession and growing of marijuana of any amount results in criminal prosecution and fines.	All illegal cannabis states
Purchase	Purchase of up to one ounce of retail marijuana at a marijuana dispensary is legal for anyone 21 years or older.	Similar to Alaska, California, Colorado, & Oregon	Anyone with written medical consent may purchase up to 2.5 ounces of marijuana for medical purposes at a dispensary.	Similar to Arizona, Illinois, & Maine	Purchase of marijuana of any amount and from any source results in criminal prosecution and fines.	All illegal cannabis states

Measures Administered Prior to Randomization.

Demographic Measures. Participants were asked to provide demographic information on age, gender, race/ethnicity, school level, year in college, grades in school, and current and past state of residency prior to college (Youth Risk Behavior Survey Questionnaire, 2015). Gender categories included "man," "woman," and "other," which was recoded to exclude "other" categories from all analyses due to low frequencies. Race/ethnicity categories included "White or European-American," "Black, Afro-Caribbean, or African American," "Asian American," "American Indian or Alaska Native," "Native Hawaiian or Other Pacific Islander," "Middle Eastern or Arab American," "Multiracial," or "Other." Participants were also asked "Do you consider yourself Hispanic/Latino(a)?" with response options "Yes" and "No." If a respondent indicated that they considered themselves to be Hispanic/Latino, they were classified as only Hispanic/Latino, and this variable was collapsed into the race/ethnicity variable. Race/ethnicity was recoded to "White," "Black," "Asian," "Hispanic/Latino," and "Multiracial/Other" due to low frequencies. School level included the following categories: "high school graduate," "GED or equivalent," "some college/no degree," "associate degree," "bachelor's degree," "master's degree," and "professional or doctoral degree." School level was recoded to "high school or GED," "some college/no degree," and "associate's or bachelor's degree" due to low frequencies. Year in college categories included "first year," "second year," "third year," "fourth year," and "fifth or more year." School grades categories included "Mostly A's," "Mostly B's," "Mostly C's," "Mostly D's," "Mostly F's," "None of these grades," and "Not Sure." School grades were recoded to "Mostly A's," "Mostly B's," "Mostly C's, D's or F's," and "Not sure." For these

analyses, respondents who reported "Not sure" for school grades were excluded. For current and past state of residency, a drop-down list of US states was provided.

Cannabis Use Patterns. Lifetime (yes/no), past 12-month (number of days), past 30-day (number of days), and past 30-day occasions (number of occasions) of cannabis were determined by adapting questions from the MTF questionnaire (L. Johnston, Miech, O'Malley, Bachman, & Schulenberg, 2015) and the NSDUH (CBHSQ, 2015). Among lifetime cannabis users, age of cannabis initiation, cannabis prescription status (yes/no), and methods of lifetime use were assessed; however, age of cannabis initiation was not used for analyses and will not be discussed further. Methods of cannabis administration used in their lifetime were determined by listing the following methods: "joint or spliff (marijuana cigarette with or without tobacco)" [joint], "blunt (cigar with marijuana with or without tobacco)" [blunt], "bowl or pipe that does not include water (glass of homemade pipe/apple pipe)" [bowl/pipe], "bong or water pipe (bucket/gravity)" [bong], "hot knife," "rig (typically used with concentrates and a blowtorch or electric heat source)" [rig], "Vaporizer or other electronic device (Volcano or PAX) [vaporizer]," "edibles (brownies, teas, tinctures, sprays)" [edible], or "some other way." Lifetime use of types of cannabis were determined by the following options: "dried marijuana (bud, weed)," "butane hash oil (BHO), kief, shatter, wax, rosin, or another form of concentrate," "cooked (tincture, spray, cannabutter)," or "some other way." Lifetime methods of cannabis administration and lifetime use of types of cannabis were not used for analyses and will not be discussed further. Only users who reported using cannabis at least once in the past 12 months were asked about past 30-day use. Among past 30-day users, occasions and days of cannabis administration methods and cannabis types used were assessed (using same list of methods and types above). The frequency

of administration method and cannabis type used (number of occasions for each method and type endorsed) also was measured. Types of cannabis used in the past 30 days were not used in analyses; therefore, will not be discussed further. The past 30-day occasion frequency of joint, blunt, bowl/pipe, bong, and edible were recoded where 0 = 0 occasions, 1 = 1-10 occasions, and 2 = 10 or more occasions. Past 30-day occasion frequency of vaporizer and rig were combined and recoded into a dichotomous item where 0 = 0 occasions and 1 = 1 or more occasions. The amount of cannabis used in the past 30 days ("Do you know how much marijuana you have used (in ounces) during the last month?") was assessed; response options: "None," "less than ½ ounce," "about ½ ounce," "about 1 ounce," "about 2 ounces," "3 to 5 ounces," "6 or more ounces," "6 or more ounces," and include "Don't know." Current state of cannabis intoxication (yes/no) during the survey administration was assessed (Davis et al., 2014; Schauer, King, et al., 2016) of all lifetime cannabis users. Preferred type of cannabis and preferred method of cannabis administration were also assessed. Amount of cannabis used in the past 30 days, current state of cannabis intoxication, preferred type of cannabis, and preferred method of cannabis administration were not included in analyses; therefore, they will not be discussed further.

Cannabis Dependence. Cannabis dependence was assessed using the Severity of Dependence Scale for cannabis users (van der Pol et al., 2013). The scale contains five items that determine the degree of cannabis dependence. All five items started with the same stem "During the past year…" The first four items were "… did you think your use of marijuana was out of control?" "…did the prospect of missing a dose of marijuana make you anxious or worried?" "…did you worry about your use of marijuana?" and "…did you wish you could stop the use of marijuana?" For the first four items, response options included "never/almost never (1),"

"sometimes (2)," "often (3)," and "always/nearly always (4)." The fifth item was "…how difficult did you find it to stop, or go without marijuana?" with response options as "not difficult (1)," "quite difficult (2)," "very difficult (3)," and "impossible (4)." Responses were totaled with a maximum score of 15.

Alcohol Use Patterns. Lifetime (yes/no) alcohol use was determined by adapting questions from the NSDUH (CBHSQ, 2015). The item asked, "Have you ever, even once, had a drink of any type of alcoholic beverage?"

Tobacco Use Patterns and Tobacco Dependence. Lifetime and 30-day use (number of days) of tobacco products were included "Cigarettes," "Traditional cigars (Macanudo, Romeo y Julieta, or Arturo Fuente)," "Pipe (with tobacco)," "Little cigars/cigarillos (like Black & Milds, Swisher Sweets, or Phillies Blunt)," "E-cigarettes (like BLU or NJOY)," "Chewing tobacco (like Levi Garrett, Red Man, or Beech Nut)," "Dip/snuff (like Skoal or Copenhagen)," "Snus (like Camel Snus)," "Dissolvable tobacco products (like Ariva, Stonewall, Camel Orbs, Sticks or Strips)," "Hookah/shisha (hookah tobacco)," and "Nicotine replacement products (like gum, patches, lozenges)" (A. M. Cohn, Johnson, Rath, & Villanti, 2016; Rath et al., 2016). Past 30-day tobacco use by product was dichotomized to "yes" or "no." The first type of tobacco product ever used and the age of tobacco initiation were assessed, but were not used in the current analyses, as well as lifetime tobacco use; therefore, these variables will not be discussed further. Fagerström Test for Nicotine Dependence was also assessed, but was not used for the current analyses and will not be discussed further (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991).

Baseline Cannabis Behavioral Intention. This scale, adapted from the marijuana behavioral intention scale (Armitage, Armitage, Conner, Loach, & Willetts, 1999), consists of three items: "I intend to use cannabis/marijuana," "I plan to use cannabis/marijuana," and "I want to use cannabis/marijuana." Responses range from (1) "Definitely do not" to (7) "Definitely do" ($\alpha = 0.98$). Responses were totaled, and the maximum score was 21.

Harm Perceptions. Harm perceptions were determined by asking "How harmful do you think that the following products are to your health?" ($\alpha = 0.94$). Responses ranged from (1) "Extremely harmful" to (7) "Not harmful at all" and included (8) "Don't know." Harm perceptions were determined for the following items: "tobacco cigarettes," "smokeless tobacco," "electronic cigarettes," "hookah/shisha," "little cigars/cigarillos," "marijuana used in a joint or spliff," "marijuana used in a blunt," "marijuana used in a bowl or pipe that does not include water," "marijuana used in a bong or waterpipe," "marijuana used with a hot knife," "marijuana used with a rig," "marijuana used with a vaporizer or other electronic device," and "marijuana in an edible form." Tobacco-product harm perceptions were not used in the current analysis; therefore, they were excluded. Cannabis-product harm perceptions were averaged across cannabis products assessed excluding "marijuana used with a hot knife" and "marijuana used with a rig" due to a high proportion of cases that responded "don't know." Cases that responded "don't know" to any cannabis harm perception item were also excluded.

Brief Sensation Seeking Scale. Sensation seeking was measured with the Brief Sensation Seeking Scale (BSSS; $\alpha = 0.75$; Hoyle, 2002). This scale contains eight items and measures the amount to which one agrees or disagrees with engaging in risky activities (e.g., "I like to do frightening things" and "I would like to try bungee jumping"). Responses range from (1)

"Strongly disagree" to (5) "Strongly agree." The scale was recoded by averaging scores across items (Hoyle, 2002).

Measures Administered Post-Randomization.

Attitudes. Attitudes in the framework of the TPB are beliefs about a behavior. Attitudes also capture the degree to which a person positively or negatively values a behavior ($\alpha = 0.97$; (Glanz, 2015). Attitudes about cannabis use were measured using an adapted 7-point bipolar scale (Armitage et al., 1999). The scale includes four items, which begin with the same stem "My using cannabis would be…" Responses range from (1) "bad, unfavorable, negative, unsatisfactory" to (7) "good, favorable, positive, satisfactory" and were totaled for a maximum score of 28.

Descriptive Norms. Descriptive norms are perceptions about others' behavioral patterns ($\alpha = 0.74$; (Glanz, 2015). For the present study, two adapted items were used for measuring perceptions of prevalence of cannabis use (e.g. "Most people my age have tried cannabis/marijuana," "Most people my age smoke cannabis/marijuana regularly"; (Ito, Henry, Cordova, & Bryan, 2015). Responses range from (1) "Strongly disagree" to (7) "Strongly agree." Descriptive norms were not used in data analysis.

Injunctive Norms. Injunctive norms are one's perceptions of whether peers and other important people approve of the behavior. Injunctive norms were measured with three adapted items ($\alpha = 0.77$; e.g. "My friends think I should use cannabis/marijuana," "My parents think I should use cannabis/marijuana," "People who are important to me think I should use cannabis/marijuana"; Ito et al., 2015). Responses range from (1) "Strongly disagree" to (7) "Strongly agree" and were totaled for a maximum score of 21.

Attention Check. In order to avoid satisficing among participants, an attention check was included (e.g., "If you read this question, please leave the answer blank"). Responses range from (1) "Strongly disagree" to (7) "Strongly agree." Participants who responded to this question were excluded from analyses (n = 18).

Perceived Behavioral Control. Perceived behavioral control is the amount of self-control one has over a behavior. Perceived behavioral control was measured with three items (α = 0.69; e.g., "Whether or not I use cannabis/marijuana is entirely up to me," "How much personal control do you feel you have over using cannabis/marijuana?," "How much do you feel that using cannabis/marijuana is beyond your control?"; Armitage et al., 1999). Responses range from (1) "Strongly agree, very little control, very much so" to (7) "Strongly disagree, complete control, not at all." Responses were totaled for a maximum score of 21.

Self-Efficacy. Although similar to perceived behavioral control, self-efficacy is the perceived ability one has to perform a behavior. The self-efficacy measure consisted of four items: "I believe I would have the ability to use cannabis/marijuana" "To what extent do you see yourself as being capable of using cannabis/marijuana?" "How confident are you that you would be able to use cannabis/marijuana?" "If it were entirely up to me, I am confident that I would be able to use cannabis/marijuana" (α = 0.95; Armitage et al., 1999). Responses range from (1) "Definitely do not, very incapable of using cannabis/marijuana, very unsure, strongly disagree" to (7) "Definitely do, very capable of using cannabis/marijuana, very sure, strongly agree. Responses were totaled for a maximum score of 28.

Post-Randomization Behavioral Intention. This scale, adapted from the marijuana behavioral intention scale (α = 0.98; (Armitage et al., 1999), consisted of three items: "I intend to

use cannabis/marijuana," "I plan to use cannabis/marijuana," and "I want to use cannabis/marijuana." Responses range from (1) "Definitely do not" to (7) "Definitely do." Responses were totaled, and the maximum score was 21.

Data Analysis

Following data cleaning and recoding procedures described above, statistical analyses were conducted using IBM SPSS (Version 22), STATA (StataCorp, 2015), and Latent Gold 4.5 (Statistical Innovations Inc., 2008). Overall sample descriptives were performed on the included sample as well as bivariate comparisons for demographic items between those that were excluded from primary analyses.

Hypothesis 1 was analyzed using LCA with Latent Gold 4.5. First, individuals who endorsed using cannabis on at least one occasion in the past 30 days were selected (n = 208). Latent class indicator variables included frequency of past-month occasions used for six methods of cannabis consumption assessed: joint, blunt, bowl/pipe, bong, edible, and vaporizer/rig. Responses for vaporizer and rig use were combined due to low frequencies. The item assessing hot knife use was excluded from this analysis due to low use frequencies (n = 1) and the item assessing cannabis use "some other way" was recoded by hand wherein each item was assessed and combined with other methods of administration categories. An exploratory strategy was used to build the model, increasing the number of classes until a class solution that adequately fit the data was determined. Ten latent class models were estimated to identify underlying groups of cannabis users based on methods of cannabis administration. The Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) were used as global fit indices as well as consideration of parsimony (fewest number of parameters; Npar) and low likelihood of

classification error to determine the appropriate number of latent classes in the model (Evans-Polce et al., 2016; Haardorfer et al., 2016; Nasim et al., 2016; Tzilos et al., 2016). The L^2 statistic was also used to determine model fit. The L^2 statistic specifies the associations that are unexplained in the model with lower L^2 values indicating a better model fit. Additionally, in order to test more precisely for model fit, bootstrapping was used. Bootstrapping accounts for violations of the assumption that the L^2 statistic has a chi square distribution (Vermunt & Magidson, 2005).

Hypothesis 2 could not be analyzed as planned. Due to low frequencies in the 4-class model from the LCA, there was insufficient power to conduct regression analyses even between the two largest classes; therefore, descriptive and bivariate results are reported. Bivariate analyses were conducted with three out of the four classes identified (Low-Blunt, Low-Bong, and Mod-Poly classes), while the High-Poly class could not be included in these bivariate analyses due to low frequencies. Comparisons between LCA classes were performed with the following variables: gender, race/ethnicity, school grades, past 30-day tobacco/nicotine use (collapsed across products), past 30-day use of individual tobacco/nicotine product types (cigarettes, traditional cigars, pipes, little cigars, electronic cigarettes, chew, dip/snuff, and hookah), lifetime alcohol use, BSSS score, cannabis dependence score, cannabis harm perceptions, and average cannabis occasions per month. Cases with "Other" as gender were excluded from Hypothesis 2 analyses, as well as cases with "Not sure" for school grades (n = 4), resulting in a sample size of 204 for Hypothesis 2.

For Hypothesis 3, equivalence of groups randomized to each cannabis policy condition (three levels; legal-policy, medical-policy, illegal-policy) was assessed using bivariate tests

examining demographic items (gender, age, race/ethnicity), level of school attainment, year in college, school grades, current and previous state of residence, lifetime alcohol use, medicinal cannabis prescription, past-30 day tobacco use, lifetime cannabis use, past year cannabis use, past 30-day cannabis use, and baseline intentions to use cannabis. Items that differed significantly between cannabis policy conditions were included as covariates in the one-way ANCOVA models. Prior to conducting planned ANCOVAs, normality was assessed visually for each post-randomization outcome: cannabis attitudes, injunctive norms, perceived behavioral control, self-efficacy, and post-randomization intentions to use cannabis. Perceived behavioral control exhibited an extremely strong rightward skew (skewness = -1.87 and kurtotis value = 4.45) due to a large proportion of responses at the highest value; this variable was transformed using the reflect and inverse formula (new variable = 1/(K – old variable) where K = largest possible value +1). Following any required transformations, between-subjects one-way ANCOVA were conducted for each post-randomization outcome. If the overall ANCOVA F-test was significant, post-hoc comparisons were completed using the Bonferroni correction to identify mean differences on dependent variables between each cannabis policy condition.

Results

Total Sample Descriptives

Table 5 displays demographics, cannabis use characteristics, and other substance use characteristics for the total sample (N = 457). Over two-thirds of the sample was female, and the average age of the sample was 20 years old. The sample was racially/ethnically diverse with 42.5% identifying as "White or European-American," 17.7% identifying as "Black, Afro-Caribbean, or African American," 14.4% identifying as "Asian-American," 11.6% identifying as "Hispanic/Latino," and 13.8% identifying as Multiracial or "Other." Over two-thirds had used any tobacco product in the past month, and 91.7% of the sample had drank alcohol in their lifetime. Most of the sample had used cannabis in their lifetime (72.9%), 61.5% had used cannabis in the past year, and 45.5% had used cannabis in the past 30 days. Of past 30-day cannabis users, the most frequently used methods of cannabis administration were bong and blunt (over half of the sample) with bowl/pipe and joint used slightly less frequently (between 40-50%; see **Table 6**). The least frequently used methods were edible and vaporizer/rig. Among past 30-day users, bong was used on the most occasions and days per month, followed by blunt and bowl/pipe.

Descriptive analyses were conducted for the demographics of participants who were excluded from the analyses (n = 86), and bivariate analyses were conducted to compare demographics between included and excluded participants. A third of participants did not report age (31.4%); however, of those that did report age, the mean age was 20 years old. There was insufficient evidence to suggest there was a significant age difference between included and excluded participants. Similar patterns were reported for race/ethnicity; a third of participants did

Table 5. Total Sample Descriptives

Characteristic	Total N = 457 n (%) or M (SD)
Gender	
Male	147 (32.2%)
Female	307 (67.2%)
Other	3 (0.7%)
Age in years	20.04 (2.88)
Race	
White or European-American	194 (42.5%)
Black, Afro-Caribbean, or African American	81 (17.7%)
Asian-American	66 (14.4%)
Hispanic/Latino	53 (11.6%)
Multiracial/Other	63 (13.8%)
Level of school attainment	
High school or GED	210 (46.0%)
Some college/no degree	188 (41.1%)
Associate's or Bachelor's degree	57 (12.5%)
Missing	2 (0.4%)
Year in college	
1st	206 (45.1%)
2nd	95 (20.8%)
3rd	81 (17.7%)
4th	44 (9.6%)
5th or more	20 (4.4%)
Missing	11 (2.4%)
School grades	
Mostly A's	125 (27.4%)
Mostly B's	246 (53.8%)
Mostly C's, D's, or F's	77 (16.8%)
Not sure	6 (1.3%)
Missing	3 (0.7%)
Current state of residence	
Maryland	2 (0.4%)
New Jersey	1 (0.2%)
Virginia	454 (99.3%)
Past state of residence	
Virginia	405 (88.6%)
Other state	52 (11.4%)
Lifetime alcohol use	419 (91.7%)
Past 30-day tobacco use	306 (67.0%)
Medicinal cannabis prescription	0 (0%)
Lifetime cannabis use	333 (72.9%)
Past year cannabis use	281 (61.5%)
Past 30-day cannabis use	208 (45.5%)

Table 6. Characteristics of Past 30-day Users by Cannabis Administration Method

	Proportion of past 30-day cannabis users* (%)	Average cannabis use occasions in past 30 M (SD)	Average cannabis use days in past 30 M (SD)
Joint	40.0%	3.1 (8.7)	2.4 (5.8)
Blunt	54.8%	4.4 (9.8)	3.9 (7.3)
Bowl/pipe	50.0%	3.8 (8.6)	3.6 (7.1)
Bong	54.8%	6.8 (15.0)	4.9 (8.8)
Edible	27.4%	0.5 (1.3)	0.5 (1.2)
Vaporizer/rig	19.2%	2.5 (11.9)	1.5 (5.4)

Note: Asterisks (*) indicate these groups are non-exclusive. Mean (SD) occasions and days reported were specific to that method among past 30-day users.

Table 7. Latent Class Model Comparisons

Number of classes	AIC	BIC	Class.Err.	L^2	Npar	*p*
1	2051.163	2084.538	0	421.6165	10	3.00E-18
2	1915.844	1985.932	0.0212	264.2972	21	0.00017
3	1894.96	2001.761	0.0179	221.4135	32	0.012
4	**1888.8**	**2032.314**	**0.1111**	**193.2536**	**43**	**0.065**
5	1887.246	2067.473	0.1533	169.6994	54	0.18
6	1886.813	2103.753	0.0703	147.2663	65	0.39
7	1889.126	2142.779	0.0811	127.5796	76	0.59
8	1892.753	2183.119	0.0792	109.2069	87	0.77
9	1896.935	2224.014	0.0602	91.3888	98	0.9
10	1913.41	2277.201	0.0718	85.8632	109	0.82
Bootstrapped 3	1894.96	2001.761	0.0179	221.4135	32	0.012
Bootstrapped 4	**1888.8**	**2032.314**	**0.1111**	**193.2536**	**43**	**0.065**

Note: **Bolded** text indicates final model selected. Class. Err. indicates classification error. Npar indicates number of parameters.

not report their race/ethnicity (33.7%). Of those that did report their race/ethnicity, 15.8% identified as "White or European-American," 21.1% identified as "Black, Afro-Caribbean, or African American," 21.1% identified as "Asian-American," 19.3% identified as "Hispanic/Latino," and 22.8% identified as Multiracial or "Other." Chi-square analyses indicated there were significant differences of race/ethnicity between included and excluded participants ($p < 0.005$). Among participants who were excluded, 36% did not report their gender, and among those who did report gender, 47.3% identified as male and 52.7% identified as female. There was insufficient evidence to suggest there was a significant difference between the distribution of gender of included and excluded participants.

Hypothesis 1 Results – LCA

Based on the BIC, the fit of the model improved from a 1-class model (2084.54) to the 2-class model (1985.93); however, the model fit weakened for the proceeding models (2001.76 – 2277.20; See **Table 7**). Based on the AIC, the fit of the model improved from the 1-class model (2051.16) to the 6-class model (1886.81), but weakened following the 6-class model to the 10-class model (1886.81 – 1913.41). Classification errors remained below 15% for all models. The 1-class model had the highest L^2 statistic (421.62) with gradually decreasing values with each subsequent model (264.30 – 85.86). The 1-class model had the lowest number of parameters (10), and the number of parameters increased with each subsequent model (21 – 109). Based on the AIC, BIC, classification error, L^2 statistics, number of parameters, and the p-value, the 4-model class was chosen as the best fit. The 4-class model with and without bootstrapping had an AIC of 1888.8, a BIC of 2032.3, a classification error of 11.1%, an L^2 statistic of 193.3, 43 parameters, and $p = 0.065$.

Table 8 displays the conditional probabilities and the assigned labels of the selected 4-class model. Conditional probabilities ranging from 0-0.30 are considered low, 0.31-0.60 are considered moderate, and 0.61-0.99 are considered high (personal communication with A. Nasim; Nasim et al., 2012; Nasim et al., 2016). The Low-Blunt class was the largest class, representing 60.1% of past 30-day cannabis users (n = 125). The Low-Blunt class was characterized by a high probability of using blunts 1-10 times per month and high probabilities of using joints, bowls/pipes, bongs, edibles, and vaporizers/rigs 0 times per month. The Low-Bong class contained 23.6% of past 30-day cannabis users (n = 49). The Low-Bong class had a high probability of using bongs 1-10 times per month. The Low-Bong class had high probabilities of using joints, blunts, edibles, and vaporizers/rigs 0 times per month and had a moderate probability of using bowls/pipes 0 times per month and 1-10 times per month. The Mod-Poly class consisted of 12.5% of past 30-day cannabis users (n = 26). The Mod-Poly class had high probabilities of using joints, blunts, and bowls/pipes 1-10 times per month and of using bongs 10 or more times per month. The Mod-Poly class also had high probabilities of using edibles and vaporizers/rigs in the past month. The High-Poly class was the smallest class, which accounted for 3.8% of the sample (n = 8). The High-Poly class was characterized by high probabilities of using joints, blunts, bowls/pipes, and bongs 10 or more times per month and of using edibles and vaporizers in the past month.

Hypothesis 2 Results – Descriptives

There were significant differences between the three largest LCA classes (i.e., Low-Blunt, Low-Bong, and Mod-Poly; n = 196) and the distribution of gender (p = 0.05; See **Table 9**). The Low-Blunt class consisted of 73.8% females, while the Low-Bong and Mod-Poly classes

Table 8. Latent Class Analysis Probabilities

	Low-Blunt	Low-Bong	Mod-Poly	High-Poly
Reported cluster size from Latent Gold	59.6%	23.3%	13.1%	4.0%
Actual calculated cluster size	60.1%	23.6%	12.5%	3.8%
n = 208	n = 125	n = 49	n = 26	n = 8
Past 30-day occasions of joint use				
0 times	0.64	0.89	0.07	0.02
1-10 times	0.31	0.02	0.93	0.01
10+ times	0.04	0.09	0.00	0.97
Past 30-day occasions of blunt use				
0 times	0.46	0.76	0.00	0.01
1-10 times	0.54	0.06	0.81	0.01
10+ times	0.00	0.18	0.19	0.97
Past 30-day occasions of bowl/pipe use				
0 times	0.63	0.40	0.20	0.14
1-10 times	0.33	0.46	0.69	0.14
10+ times	0.04	0.14	0.11	0.73
Past 30-day occasions of bong use				
0 times	0.68	0.19	0.00	0.02
1-10 times	0.32	0.63	0.37	0.01
10+ times	0.00	0.18	0.62	0.97
Past 30-day use of edibles				
No	0.78	0.93	0.31	0.14
Yes	0.22	0.07	0.69	0.86
Past 30-day vaporizer/rig use				
No	0.91	0.94	0.18	0.63
Yes	0.09	0.06	0.82	0.37

Table 9. Hypothesis 2 Descriptives and Bivariate Associations with Latent Class Analysis Class Status

Characteristics	Low-Blunt n = 122 n (%) or M (SD)	Low-Bong n = 48 n (%) or M (SD)	Mod-Poly n = 26 n (%) or M (SD)	*p*	High-Poly n = 8 n (%) or M (SD)
Gender				**0.045**	
Male	32 (26.2%)	20 (41.7%)	12 (46.2%)		3 (37.5%)
Female	90 (73.8%)	28 (58.3%)	14 (53.8%)		5 (62.5%)
Race/Ethnicity				**0.021**	
White	45 (36.9%)	27 (56.3%)	16 (61.5%)		4 (50.0%)
Black	31 (25.4%)	7 (14.6%)	2 (7.7%)		1 (12.5%)
Asian	8 (6.6%)	5 (10.4%)	3 (11.5%)		--
Hispanic/Latino	20 (16.4%)	1 (2.1%)	4 (15.4%)		1 (12.5%)
Multiracial/Other	18 (14.8%)	8 (16.7%)	1 (3.8%)		2 (25.0%)
School Grades				0.218	
Mostly A's	21 (17.2%)	14 (29.2%)	6 (23.1%)		--
Mostly B's	80 (65.6%)	24 (50.0%)	18 (69.2%)		3 (37.5%)
Mostly C's, D's, or F's	21 (17.2%)	10 (20.8%)	2 (7.7%)		5 (62.5%)
Past 30-day tobacco use	56 (45.9%)~	26 (54.2%)	19 (73.1%)~	**0.039**	6 (75.0%)
Past 30-day cigarettes	30 (24.6%)	18 (37.5%)	11 (42.3%)	0.088	4 (50.0%)
Past 30-day traditional cigars	5 (4.1%)	1 (2.1%)	2 (7.7%)	N/A	--
Past 30-day pipe	2 (1.6%)	--	--	N/A	--
Past 30-day little cigars	20 (16.4%)	8 (16.7%)	9 (34.6%)	0.088	5 (62.5%)
Past 30-day electronic cigarettes	6 (4.9%)*^	8 (16.7%)^	7 (26.9%)*	**0.001**	2 (25.0%)
Past 30-day chew	1 (0.8%)	1 (2.1%)	--	N/A	--
Past 30-day dip/snuff	1 (0.8%)	2 (4.2%)	3 (11.5%)	N/A	--
Past 30-day hookah	13 (10.7%)	5 (10.4%)	6 (23.1%)	0.194	--
Lifetime alcohol use	122 (100.0%)	47 (97.9%)	26 (100.0%)	N/A	8 (100.0%)
Sensation seeking (BSSS)	25.8 (5.5)	25.9 (5.2)	28.4 (4.9)	0.072	26.8 (6.2)
Cannabis dependence score	5.8 (1.7)*	6.5 (2.1)	7.4 (2.7)*	**0.008**	7.1 (2.6)
Cannabis harm perceptions	2.7 (1.4)	2.6 (1.2)	2.7 (1.2)	0.937	1.9 (0.7)
Average days of cannabis use per month	6.4 (7.7)*^	12.2 (11.3)^~	25.2 (7.7)*~	**<0.001**	28.4 (3.5)

Note: Bivariate tests (chi-square, ANOVA) and associated p-values compared data among the Low-Blunt, Low-Bong, and Mod-Poly classes; High-Poly was excluded due to low frequencies. Welch test was used due to violation of homogeneity of variance for cannabis dependence and average days of cannabis use per month. N/A indicates that at least 30% of expected cell counts were less than 5; therefore, bivariate statistical results were unreliable. Asterisks (*) indicate a significant difference at the 0.05 level between Low-Blunt and Mod-Poly. Carets (^) indicate a significant difference at the 0.05 level between Low-Blunt and Low-Bong. Tildes (~) indicate a significant difference at the 0.05 level between Low-Bong and Mod-Poly. For past 30-day tobacco use, no participants reported dissolvable tobacco, snus, or nicotine replacement therapy use.

consisted 58.3% and 53.8% females, respectively. There were significant differences between LCA class and the distribution of race/ethnicity ($p = 0.02$). The Low-Blunt class had a higher proportion of individuals of Hispanic/Latino and Black race/ethnicity than the Low-Bong and Mod-Poly classes. The Low-Bong class and Mod-Poly class primarily consisted of individuals of White race/ethnicity (56.3% and 61.5%, respectively). There were also significant differences between the three LCA classes and the distribution of past 30-day tobacco use ($p = 0.04$). Approximately 73% of the Mod-Poly class were past 30-day tobacco users compared to 46% of the Low-Blunt class and 54% of the Low-Bong class. There were significant differences between the LCA classes and endorsement of past 30-day use of electronic cigarettes ($p = 0.001$). In the Mod-Poly class, 26.9% had used an electronic cigarette in the past 30 days compared to only 16.7% in the Low-Bong class and 4.9% in the Low-Blunt class. Due to violations in homogeneity of variance, the adjusted F test (i.e., Welch statistic) indicated that there was a significant difference between the three LCA classes and cannabis dependence, $F(2, 54) = 5.327$, $p = 0.01$. There were statistically significant differences between average cannabis dependence scores for the Mod-Poly class and the Low-Blunt class, such that that Mod-Poly class had a higher cannabis dependence score. There were significant differences between the three LCA classes and average monthly cannabis use in days, $F(2, 59) = 63.747$, $p < 0.001$. There were statistically significant differences between the Low-Blunt and Low-Bong classes, the Low-Bong class and the Mod-Poly class, as well as, the Low-Blunt and Mod-Poly classes.

Hypothesis 3 Results – Cannabis Policy Conditions

Results for bivariate and ANCOVA analyses are presented in Tables 10 and 11. For bivariate associations between the cannabis policy conditions and the potential covariates, results

Table 10. Hypothesis 3 Descriptives and Bivariate Associations by Cannabis Policy Condition

Characteristic	Legal-policy n = 149 n (%) or M (SD)	Medical-policy n = 150 n (%) or M (SD)	Illegal-policy n = 147 n (%) or M (SD)	*p*
Gender				0.872
Male	46 (30.9%)	50 (33.3%)	49 (33.3%)	
Female	103 (69.1%)	100 (66.7%)	98 (66.7%)	
Age in years	20.2 (3.1)	20.0 (2.5)	19.9 (3.1)	0.578
Race				0.187
White	68 (45.6%)	71 (47.3%)	50 (34.0%)	
Black	31 (20.8%)	22 (14.7%)	25 (17.0%)	
Asian	19 (12.8%)	22 (14.7%)	23 (15.6%)	
Hispanic/Latino	16 (10.7%)	15 (10.0%)	22 (15.0%)	
Multiracial/Other	15 (10.1%)	20 (13.3%)	27 (18.4%)	
Level of school attainment				0.171
High school or GED	60 (40.5%)	72 (48.3%)	73 (49.7%)	
Some college/no degree	62 (41.9%)	62 (41.6%)	60 (40.8%)	
Associate's or Bachelor's degree	26 (17.6%)	15 (10.1%)	14 (9.5%)	
Year in college				**0.002**
1st	54 (36.7%)	66 (45.2%)	82 (56.9%)	
2nd	35 (23.8%)	36 (24.7%)	23 (16.0%)	
3rd	40 (27.2%)	20 (13.7%)	19 (13.2%)	
4th	14 (9.5%)	14 (9.6%)	16 (11.1%)	
5th or more	4 (2.7%)	10 (6.8%)	4 (2.8%)	
School grades				**0.024**
Mostly A's	34 (22.8%)	48 (32.0%)	42 (28.6%)	
Mostly B's	95 (63.8%)	68 (45.3%)	83 (56.5%)	
Mostly C's, D's, or F's	20 (13.4%)	34 (22.7%)	22 (15.0%)	
Current state of residence				N/A
Maryland	2 (1.3%)	--	--	
New Jersey	--	--	1 (0.7%)	
Virginia	147 (98.7%)	150 (100.0%)	146 (99.3%)	
Past state of residence				0.313
Virginia	129 (86.6%)	138 (92.0%)	130 (88.4%)	
Other state	20 (13.4%)	12 (8.0%)	17 (11.6%)	
Lifetime alcohol use	137 (91.9%)	136 (90.7%)	135 (91.8%)	0.908
Medicinal cannabis prescription	0 (0%)	0 (0%)	0 (0%)	--
Past 30-day tobacco use	44 (29.5%)	54 (36.0%)	51 (34.7%)	0.456
Lifetime cannabis use	102 (68.5%)	117 (78.0%)	107 (72.8%)	0.176
Past year cannabis use	84 (56.4%)	97 (64.7%)	94 (63.9%)	0.476
Past 30-day cannabis use	67 (45.0%)	66 (44.0%)	71 (48.3%)	0.186
Baseline intentions to use cannabis	8.5 (6.6)	9.8 (6.7)	10.5 (7.3)	**0.030**

Note: Welch test was used due to violation of homogeneity of variance for baseline intentions to use cannabis; N/A indicates that at least 30% of expected cell counts were less than 5; therefore, bivariate statistical results were unreliable.

Table 11. Analysis of Covariance Results for Experimental Outcomes

Outcome measure	Overall Sample M (SE)	Legal-policy M (SE)	Medical-policy M (SE)	Illegal-policy M (SE)	*p*
Attitudes about cannabis	15.1 (0.4)	16.2 (0.6)*	16.4 (0.5)^	12.6 (0.6)*^	**<0.001**
Injunctive norms	7.9 (0.2)	8.2 (0.3)	8.2 (0.3)	7.4 (0.3)	**0.045**
Perceived behavioral control (PBC)	18.5 (0.2)	18.8 (0.3)	18.6 (0.3)	18.0 (0.3)	0.170
Log-transformed PBC	0.6 (0.2)	0.7 (0.04)	0.6 (0.03)	0.6 (0.04)	0.443
Self-efficacy to use cannabis	19.8 (0.3)	20.6 (0.6)*	20.4 (0.5)^	18.3 (0.6)*^	**0.005**
Post-randomization intentions to use cannabis	10.2 (0.2)	11.0 (0.3)*	10.4 (0.3)^	9.3 (0.3)*^	**<0.001**

Note: M (SE) reported above include covariates appearing in the model evaluated at the following values: school year = 2.04, past 30-day cannabis use = 0.4577, and baseline intentions to use cannabis = 9.59. Attitude scores ranged from 7 to 28. Higher mean attitude scores indicated more favorable attitudes about cannabis. Injunctive norm scores ranged from 7 to 21. Higher mean injunctive norms scores indicated a higher agreement that social supporters think they should use cannabis. PBC scores ranged from 7 to 21. Higher mean scores for PBC indicated stronger beliefs that a person is able to use cannabis. Self-efficacy scores ranged from 7 to 28. Higher mean self-efficacy scores indicated a higher self-confidence in the ability to use cannabis. Post-randomization intentions scores ranged from 7 to 21. Higher mean post-randomization intentions scores indicated higher intentions to use cannabis. Asterisks (*) indicate a significant difference at the 0.05 level between illegal condition and legal condition. Carets (^) indicate a significant different at the 0.05 level between medical condition and illegal condition.

indicated that there were significant differences between the cannabis policy conditions and year in college ($p = 0.002$) and school grades ($p = 0.024$) as well as baseline intentions to use cannabis ($p = 0.030$; See **Table 10**). These three variables were included as covariates in the subsequent ANCOVAs, as well as past 30-day cannabis use due to this behavior's salience in the analysis outcomes.

Among the planned five ANCOVAs conducted controlling for year in school, school grades, past 30-day cannabis use, and baseline intentions to use cannabis, four outcomes had a significant effect of cannabis policy condition (see **Table 11**). There was a significant effect of cannabis policy condition on attitudes about cannabis, $F(2, 429) = 15.590$, $p < 0.001$. Post-hoc comparisons using the Bonferroni correction revealed the legal-policy and medical-policy conditions resulted in significantly more positive attitudes about cannabis relative to the illegal-policy condition ($ps < 0.05$). However, the cannabis attitudes in the legal-policy condition did not significantly differ from the medical-policy condition.

There was a significant effect of cannabis policy condition on injunctive norms for cannabis use, $F(2, 429) = 3.115$, $p = 0.045$. Post-hoc comparisons revealed there were no differences between cannabis policy conditions although descriptively the illegal-policy condition had the lowest injunctive norms relative to the medical-policy condition and the legal-policy condition.

There was insufficient evidence to suggest there was a significant effect of cannabis policy condition on perceived behavioral control, $F(2, 429) = 1.777$, $p = 0.170$.

There was a significant effect of cannabis policy condition on self-efficacy, $F(2, 429) = 5.409$, $p = 0.005$. Post-hoc comparisons using the Bonferroni correction revealed the legal-policy

and the medical-policy conditions resulted in significantly higher self-efficacy scores compared to the illegal-policy condition (*p*s < 0.05). However, the mean self-efficacy scores in the legal-policy condition did not significantly differ from the medical-policy condition.

There was a significant effect of cannabis policy condition on post-randomization intentions to use cannabis, $F(2, 429) = 10.802$, $p < 0.001$. Post-hoc comparisons using the Bonferroni correction revealed the legal-policy and medical-policy conditions resulted in significantly higher post-randomization intentions to use cannabis score relative to the illegal-policy condition (*p*s < 0.05). However, the post-randomization intentions to use cannabis score in the legal-policy condition did not significantly differ from the mean score in the medical-policy condition.

Discussion

The purpose of the current study was 1) to assess patterns of cannabis consumption among young adults using LCA, 2) to determine if these patterns were associated with differential demographics and other factors, as well as 3) to test if hypothetical cannabis policy environments influenced attitudes about cannabis, injunctive norms, perceived behavioral control, self-efficacy, and intentions to use cannabis among young adults. Approximately 450 students completed the study and 45% were current (past 30-day) cannabis users. Four latent classes of cannabis users based on frequency of past 30-day administration methods of cannabis use were identified. Three of the largest classes differed by gender, race/ethnicity, past 30-day tobacco use, past 30-day electronic cigarette use, cannabis dependence, and average days of cannabis use per month. These data reveal unique groups of cannabis users that can be targeted more effectively for prevention and intervention efforts. As this study was conducted in an illegal cannabis policy environment, it would be valuable to identify if these same sub-groups of cannabis users exist in a legal cannabis policy environment and/or medicinal cannabis policy environment. In Hypothesis 3, results indicated that legal and medicinal cannabis policy conditions increased attitudes about cannabis, injunctive norms, self-efficacy, and intentions to use cannabis relative to the illegal cannabis policy condition. These data reveal that a simple hypothetical policy manipulation can change intentions to use cannabis. Based on the TPB, these behavioral intentions may lead to changes in behaviors. It is plausible that real changes in cannabis policies can alter cannabis use; however, more research is needed in real-life situations in order to explore this association.

Hypothesis 1

For Hypothesis 1, we expected to find a large class of young adults who used combustion-based methods of cannabis (e.g., joints, blunts, bongs). However, in the current study, four latent classes were identified (Low-Blunt, Low-Bong, Mod-Poly, High-Poly), where several specific methods of administration were highlighted, as well as varying frequencies of use. Previous literature has often compared cannabis users to non-users, implying that cannabis users are a homogenous group (Lipperman-Kreda, Paschall, Robert, & Morrison, 2017; Pedersen, Hummer, Rinker, Traylor, & Neighbors, 2016); however, data from the current study revealed that there are unique sub-groups among cannabis users. The Low-Blunt and the Low-Bong classes comprised over three-quarters of the sample (84%), and both were characterized by high probabilities of using either blunts or bongs between 1-10 times per month. On the other hand, the Mod-Poly and High-Poly classes were smaller in size (4-13%) and were characterized by high probabilities of using all methods of cannabis administration and for some, at higher frequencies (10+ times per month). The Mod-Poly class was characterized by high probabilities of using edibles and rigs/vaporizers, while the High-Poly class was characterized by a high probability of using edibles but a low probability of using rigs/vaporizers.

Although several studies have conducted LCAs on cannabis users (Baggio et al., 2014; Krauss, Rajbhandari, Sowles, Spitznagel, & Cavazos-Rehg, 2017; Pearson et al., 2017), none have used this type of analysis with the inclusion of a range of cannabis methods of administration as well as use frequencies of these methods. One longitudinal Swiss study conducted between 2010 and 2011 identified sub-groups of male adult cannabis users based on methods of administration; however, the study only included frequencies of joints, cannabis

"mixed with food," and water pipes in their LCA (Baggio et al., 2014). Results indicated that joint users comprised the largest latent class, followed by users who reported low frequencies of joints, water pipes, and cannabis "mixed with food" and users who reported high frequencies of joints, water pipes, and cannabis "mixed with food" (Baggio et al., 2014). Contrasting from the Baggio et al. (2014) article, the inclusion of more methods of cannabis administration revealed a Low-Blunt class and a Low-Bong class, but similarly to the Baggio et al. (2014) study, the smallest class in both studies was the high frequency use of multiple methods of cannabis administration (i.e., High-Poly class).

Compared to studies that measured the use of different cannabis methods of administration, several similarities were apparent. The use of blunts and bongs were most frequently reported among past 30-day cannabis users in the present sample (54.8% and 54.8%, respectively), which corroborates findings from past literature among an adult population recruited online between 2010-2012 (Hughes et al., 2014). However, our results differed from a study conducted in 2014 among a representative nationwide sample of adults which reported bowl/pipe use as the most frequently endorsed method of administration (50%), followed by joints (49%), bongs (22%), and vaporizers (8%; Schauer et al., 2016). These discrepancies between studies could exist due to the changes in cannabis policies since 2010, which could have affected nationwide patterns of use and/or due to the changes in cannabis policies by state. The current study was conducted in a Mid-Atlantic state, whereas the aforementioned studies were conducted with nationwide samples (Hughes et al., 2014; Schauer et al., 2016). Also consistent with past literature, use of multiple methods was common in two latent classes (i.e., Mod-Poly and High-Poly; Hughes et al, 2014; Schauer et al., 2016).

Hypothesis 2

For Hypothesis 2, we expected to identify differences between latent classes on demographics, harm perceptions, and risk-taking behaviors. However, the LCA revealed four latent classes which limited our analyses to simpler techniques than were proposed. Therefore, bivariate statistics were conducted to describe the data. We found significant differences between three latent classes (i.e., Low-Blunt, Low-Bong, Mod-Poly) by gender, race/ethnicity, past 30-day tobacco use, past 30-day electronic cigarette use, cannabis dependence, and average days of cannabis use per month.

Low-Blunt users were primarily female (73.8%) and were more racial/ethnical diverse with a high proportion of people who identified as Black (25.4%) compared to the other classes (Low-Bong 14.6%; Mod-Poly 7.1%). Almost half of Low-Blunt users reported past 30-day tobacco use, and Low-Blunt users reported a significantly lower amount of past 30-day electronic cigarette use compared to the Low-Bong and Mod-Poly classes. Cannabis dependence was significantly lower in the Low-Blunt class compared to the Mod-Poly class, and on average, the Low-Blunt class reported the lowest number of days of past month cannabis use.

The Low-Bong class consisted of a higher proportion of females than males (58.3% vs. 41.7%), and these individuals primarily identified as White (56.3%). Over half of the Low-Bong users reported past 30-day tobacco use and significantly more Low-Bong users reported electronic cigarette use compared to the Low-Blunt class. The Low-Bong class reported a significantly higher average number of days of cannabis use per month compared to the Low-Blunt class; however, the Low-Bong class reported a significantly lower average number of days of cannabis use per month compared to the Mod-Poly class.

The Mod-Poly class also consisted of more females than males (53.8% vs. 46.2%), and they primarily identified as White (61.5%). The Mod-Poly class had the highest proportion of past 30-day tobacco users compared to the Low-Blunt and Low-Bong classes with a significant difference between the Low-Blunt and Mod-Poly classes. The Mod-Poly class also reported the highest proportion of past 30-day electronic cigarette use which was significantly higher than the Low-Blunt class and the Mod-Poly class. Cannabis dependence was highest in the Mod-Poly class, which was significantly higher than the Low-Blunt class. Finally, the average days of cannabis use per month was significantly higher in the Mod-Poly class compared to both Low-Blunt and Low-Bong classes.

The High-Poly class consisted of more females than males (62.5% vs. 37.5%) and was ethnically/racially diverse with half of the sample identifying as White and a quarter of the sample identifying as Multiracial/Other. The High-Poly class earned mostly C, D, or F grades in school. The High-Poly class endorsed the highest proportion of past 30-day tobacco use compared to the other three classes, as well as the highest proportion of past 30-day cigarette use and little cigar use. Cannabis dependence in the High-Poly class was similar to cannabis dependence scores in the Mod-Poly class. Interestingly, the High-Poly class reported the lowest cannabis harm perceptions compared to the other three classes. Finally, the High-Poly class, on average, used cannabis almost every day in the past 30 days.

There were no significant differences between the Low-Blunt, Low-Bong, and Mod-Poly classes on school grades, past 30-day cigarette, traditional cigars, tobacco pipes, little cigars, chew, dip/snuff, or hookah, lifetime alcohol use, sensation seeking, or cannabis harm perceptions.

Due to the limited literature on cannabis methods of administration, many of the current findings are unique to the current study. However, past literature has explored some correlates of specific methods of cannabis administration which can allow for some comparisons to current study result. Past literature has indicated that blunt users are more likely to identify as female and Black, non-Hispanics, which is consistent with the Low-Blunt class (A. Cohn et al., 2016; J. R. Hughes et al., 2014; Timberlake, 2009). More frequent cannabis use has been correlated with vaporizer use, which is consistent with the Mod-Poly class (D. C. Lee et al., 2016). Importantly, previous literature on correlates of cannabis administration methods has not included frequencies of administration method use. Further research is needed to replicate the findings in the current study in order to inform intervention efforts for these sub-groups of cannabis users.

The results indicate that there are unique groups of cannabis users which can be targeted for specific intervention. Evidence-based cannabis interventions most often consist of cognitive behavioral therapy, contingency management, motivational enhancement therapy, or a combination of these interventions (NIDA, 2012). Cognitive behavioral therapy involves the development of coping skills in order to manage and/or abstain from substance use (NIDA, 2012). Contingency management interventions consist of providing a monetary or voucher incentive (which acts as a positive reinforcement) to refrain from substance use (NIDA, 2012). Finally, motivational enhancement therapy is a form of counseling in which internal motivation is fostered in the client in order to promote abstinence (NIDA, 2012). Although these cannabis interventions are widely used and often result in abstinence, previous research on cannabis interventions generalize cannabis users as a homogenous group (ignoring the various methods of cannabis administration; e.g., Budney, Moore, Rocha, & Higgins, 2006; Carroll et al., 2006;

Marijuana Treatment Project Research, 2004; Schuster et al., 2016). Based on the findings from the current study, it may be useful to apply these interventions to specific groups of cannabis users. Regarding the current study, the largest latent class, the Low-Blunt class, could benefit from cognitive behavioral therapy that specifically targets blunt use and highlights its risks including the harms of acute exposure to tobacco products (i.e., in the blunt wrap).

Although cannabis interventions often target cannabis users without the consideration of the various methods of cannabis administration, cannabis interventions also focus on and are sought by dependent cannabis users. The Mod-Poly and High-Poly classes had the highest levels of cannabis dependence and frequency of use, suggesting potentially more severe substance use disorder symptomology and that more intensive treatment strategies, such as a combination of cognitive behavioral therapy and contingency management, would benefit these individuals. Contingency management interventions have often been used with adolescent cannabis users; however, contingency management interventions may be also useful for young adult cannabis users who may not have a desire to abstain from cannabis use. Previous literature conducted in 2009 on young adults' interest in receiving cannabis treatment indicated that less frequent cannabis use was associated with a decreased interest to participate in cannabis treatment (Buckner, Ecker, & Cohen, 2010). Due to the low frequency of cannabis use in the Low-Blunt and Low-Bong classes in the current study, these users may benefit from motivational enhancement therapy, in order to increase the desire to participate in cannabis treatment and abstain from cannabis use. Importantly, all classes were likely to report concurrent tobacco use (46-75%) consistent with other literature regarding the co-occurrence of substance use behavior (Agrawal & Lynskey, 2009; Schauer, Berg, Kegler, Donovan, & Windle, 2015, 2016). Effective

interventions may be best served to incorporate features of tobacco and cannabis use cessation; it may be most advantageous to target both substances at the same time (Becker, Haug, Kraemer, & Schaub, 2015; Becker, Haug, Sullivan, & Schaub, 2014; Becker et al., 2013). These results also indicate a need for clinical practitioners and researchers to avoid treating past month cannabis users as one homogenous group during assessment. Asking about the individual's unique patterns of cannabis use (i.e., their methods of cannabis administration) lends a better understanding to the individual's specific harm potential.

The latent classes identified in the current study were characterized by unique combinations of cannabis methods of use which may be related to harmfulness. Available research has indicated that there may be differential health effects associated with the various methods of cannabis administration. For example, combustion-based methods of cannabis administration (e.g., blunts and joints) are associated with increased coughing, exposure to carbon monoxide, and the development of lung disease and cancer (Martinasek et al., 2016; Yayan & Rasche, 2016). In the current study, the two largest classes, Low-Blunt and Low-Bong, were characterized by methods of cannabis administration that rely on combustion. These two classes may experience similar combustion-related negative health effects. The Mod-Poly and High-Poly classes were characterized by use of all methods of administration including combusted and non-combusted. These classes may be exposed to combustion-based negative health effects, as well as negative health effects from using other methods of administration. For example, both the Mod-Poly and High-Poly classes resulted in high probabilities of using edibles, and the use of edibles is associated with mouth irritation (Cho et al., 2005). It is unknown whether the use of multiple methods of cannabis administration is associated with a

greater number of negative health effects. More research is needed to explore the potential additive negative health effects of multiple methods of cannabis administration.

Hypothesis 3

The purpose of Hypothesis 3 was to test if hypothetical cannabis policy environments influenced attitudes about cannabis, injunctive norms, perceived behavioral control, self-efficacy, and intentions to use cannabis among young adults. We expected the legal-policy condition would elicit the highest intentions to use cannabis, followed by the medical-policy condition and the illegal-policy condition. We expected self-reported attitudes, injunctive norms, perceived behavioral control, and self-efficacy to be highest in the legal-policy condition and lowest in the illegal-policy condition.

Consistent with our hypotheses, attitudes about cannabis were significantly different across cannabis policy environments when controlling for year in school, school grades, past 30-day cannabis use, and baseline intentions to use cannabis. The illegal drug condition was associated with significantly less favorable attitudes about cannabis compared to the legal-policy condition and the medical-policy condition. The medical-policy condition was associated with the most favorable attitudes about cannabis, but the medical-policy condition did not significantly differ from the legal-policy condition. There were significant differences between cannabis policy environments and injunctive norms. The legal- and medical-policy conditions were associated with higher injunctive norms compared to the illegal-policy condition. More simply stated, those in the legal- and medical-policy conditions more often agreed that their social supporters (i.e., family members and important others) think they should use cannabis. Inconsistent with our hypotheses, perceived behavioral control did not differ across cannabis

policy environments. Self-efficacy to use cannabis differed significantly across cannabis policy environments. The legal-policy and the medical-policy conditions were associated with significantly higher self-efficacy to use cannabis scores compared to the illegal-policy condition. The illegal-policy condition was associated with significantly less self-efficacy to use cannabis compared to the medical-policy condition and the legal-policy condition. The legal-policy condition had the highest self-efficacy to use cannabis scores, but the legal-policy condition did not significantly differ from the medical-policy condition. Finally, the post-randomization intentions to use cannabis differed across cannabis policy conditions. Similar to previous results, the legal-policy and medical-policy conditions were associated with significantly higher intentions to use cannabis compared to the illegal-policy condition, with the legal-policy condition resulting in the highest intentions to use cannabis.

These results indicate that using an experimental design with a behavior change theory rationale results in differences in intentions to use cannabis across hypothetical cannabis policy conditions. Intentions to use is the most closely-related antecedent to actual behavior in the TPB. Therefore, these data could point to potential changes in cannabis use patterns due to cannabis policy changes, such that more relaxed cannabis policies elicit higher intentions to use cannabis among young adults. Although these results were found in the current study, longitudinal data collected in California from 1995 to 1999 (prior to and following the legalization of cannabis for medicinal purposes) indicated that actual cannabis use behaviors did not increase among all age groups as a function of legalizing medicinal cannabis in 1996 (Khatapoush & Hallfors, 2004). More recent research using combined longitudinal data from MTF (from 1991-2014), the National Longitudinal Surveys of Youth (from 1997-2005), the YRBS (from 1991-2011) and the

NSDUH (from 2002-2013) indicated that adolescents' use of cannabis did not significantly increase after medical cannabis laws were enacted; however, in the same study, according to the NSDUH (from 2004-2013) and the National Institute on Alcohol Abuse and Alcoholism surveys (from 1991-2012), cannabis use increased among adults after legalization of cannabis for medicinal use (Carliner, Brown, Sarvet, & Hasin, 2017). This discrepancy provides motivation for more longitudinal research across many states to determine the real-life, long-term effects of cannabis policy changes across different ages.

Results from Hypothesis 3 also indicated that attitudes about cannabis were significantly most favorable in the medical-policy and legal-policy conditions compared to the illegal-policy condition. This finding is unsurprising, given that favorable cannabis attitudes tend to coincide with the legalization of cannabis for recreational and medicinal purposes. This finding is consistent with a study that used data from the NSDUH (from 2003-2011) on the differences between adults' cannabis attitudes in Colorado (during which the state allowed the use of cannabis only for medicinal purposes) compared to 34 states that had illegal cannabis policies at the time (Schuermeyer et al., 2014). Results indicated that adults in Colorado had significantly higher approval rates for cannabis use compared to adults in states with illegal cannabis laws (Schuermeyer et al., 2014). Importantly, among Colorado and states with illegal cannabis laws, approval rates for cannabis increased from 2003 to 2011 (Schuermeyer et al., 2014). Taken together, evidence suggests that less restrictive cannabis policy is associated with more favorable attitudes toward cannabis. Further research should continue to monitor cannabis attitudes in states with legalized cannabis for recreational and/or medicinal purposes, as well as, monitor nationwide trends on cannabis attitudes.

Limitations

There were several limitations to the current study. One common to surveys among specific college-based samples relates to generalizability. It is possible that results found here may be specific to the geographic region and time due to differences in environmental influences as well as relevant policies. Social desirability bias also may have influenced self-reports of marijuana use (Welte & Russell, 1993); although the data collection techniques (data were never linked to participant names) may have reduced this effect. Previous studies have also relied on self-report for other substance behaviors that are restricted (i.e., alcohol) and shown them to be valid and reliable (Del Boca & Darkes, 2003). However, recall errors may have also occurred in the current study. Future research should utilize multiple methods of self-report (e.g., timeline follow back) in order to increase reliability (Hjorthoj, Hjorthoj, & Nordentoft, 2012). Another limitation to the current study is the use of a hypothetical policy environment to invoke changes in behavioral intentions. Although the results of the study showed a successful policy manipulation, conducting this study across US states with varying policy environments would have been stronger in order to better generalize to other populations. Regarding methods, the survey did not ask about health status of the participant themselves or of their family members. Differences in these variables could have affected the injunctive norms which asked about the perception of family members' opinions about cannabis use. For example, if a family member is sick and uses cannabis medicinally, injunctive norms of the participant could be elevated compared to participants without this influence. Although unknown prior to the study, a larger sample size would have allowed for sufficient power to conduct regression analyses for Hypothesis 2.

Conclusions and Future Directions

The current study identified four unique sub-groups of cannabis users and differential demographics, tobacco, and cannabis use behaviors between these groups. Using the results from this study, these sub-groups of cannabis users can be more effectively targeted for intervention efforts. These results also provide support for the notion that cannabis users have heterogeneous use patterns which may be associated with differential harms. Results from the current study also indicated that a recreationally and medicinally legalized cannabis policy environment increased attitudes, injunctive norms, self-efficacy, and intentions to use cannabis. Using the TPB as context for these findings, cannabis use behaviors could increase due to the legalization of cannabis for recreational or medicinal purposes. Therefore, studying attitudes about cannabis, self-efficacy to use cannabis, and intention to use cannabis in real-life situations in a variety of states, pre- and post-policy changes would be beneficial to fully understand the effects of policy changes.

Appendix A

Below is an example of the legal-policy condition prompt which was shown to the participant immediately after randomization to condition.

The next several sections will ask you to answer questions in the context of the situation stated below.

Imagine you live in a state where marijuana is **medically** and **recreationally** LEGAL.

- Anyone over the age of 21 may use marijuana for recreational purposes.
- Anyone with written medical consent may use marijuana for medical purposes.
- Anyone over the age of 21 may possess up to 1 ounce of marijuana.
- Anyone with written medical consent may possess up to 2.5 ounces of marijuana for medical purposes.
- Anyone over the age of 21 may grow up to 6 marijuana plants.
- Anyone over the age of 21 may purchase up to 1 ounce of marijuana for recreational purposes at a dispensary.
- Anyone with written medical consent may purchase up to 2.5 ournces of marijuana for medical purposes at a dispensary.

>>

Appendix B

Below is an example of the legal-policy condition prompt which was shown to the participant at the top of each measure after randomization to condition.

Imagine you live in a state where recreational and medical marijuana use is LEGAL...

my using marijuana would be...

Bad 1	2	3	4	5	6	Good 7

my using marijuana would be...

Unfavorable 1	2	3	4	5	6	Favorable 7

my using marijuana would be...

Negative 1	2	3	4	5	6	Positive 7

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