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Research Paper

The impacts of potency, warning messages, and price on preferences for Cannabis flower products

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ABSTRACT

Background: Recreational cannabis has been legalized in 11 states and Washington DC in the US. However, little is known about individual preferences for legal cannabis products. This study estimated the impacts of tetrahydrocannabinol (THC), cannabidiol (CBD), warning messages, and price on preferences for cannabis flowers.
Methods: A cross-sectional online survey with discrete choice experiments was implemented in October 2017. A sample of 2400 adults aged 21 years or older were recruited from 6 US states with recreational cannabis legalization, consisting of 1200 past-year nonusers and 1200 past-year users. Each respondent was randomly assigned to 12 discrete choice scenarios, each asking them to choose from an opt-out option and 3 cannabis flower products with varying levels in THC, CBD, warning messages, and price. The impacts of product attributes on individual choices were analyzed with nested logit regressions.
Results: Both cannabis nonusers and users preferred higher CBD and lower price. Users also preferred higher THC. The results on warning messages were mixed: graphic warning on drugged driving and text warning message had positive impacts on nonusers' and users' preferences for cannabis flowers, respectively, whereas FDA disapproval disclaimer had negative impacts on nonusers' preferences. Heterogeneities in preferences were revealed among nonusers by former use status and among users by reason of use. Particularly, medical cannabis users were not as responsive to THC as recreational cannabis users or dual users were. Regarding relative importance of the attributes, all respondents but medical cannabis users perceived price as the most important attribute (relative importance 51–64%), whereas medical cannabis users perceived CBD as the most important attribute (relative importance 47%).
Conclusion: The findings indicated that product characteristics may have influences on US adults' choices of legal cannabis flower products and may deserve consideration for cannabis regulatory framework.

Introduction

Cannabis is the most commonly used illicit drug in the US that is prohibited at the federal level. During 2002–2017, past-year users increased from 11% to 15% (37.8 million in 2017) and past-month users increased from 6% to 10% (24.4 million in 2017) (SAMHSA, 2017). There is some evidence on therapeutic effects of cannabis on certain conditions such as chronic pain, chemotherapy-induced nausea and vomiting, and multiple sclerosis (NationalAcademies, 2017), but recreational cannabis use is associated with cannabis use disorders, respiratory and cardiovascular diseases, and increased risk of motor vehicle accidents (Hall & Degenhardt, 2009).

Despite the federal prohibition against cannabis in the US, since 2012, recreational cannabis has been legalized in 11 states and Washington DC where over a quarter of US population live (LawAtlas, 2019). Recreational cannabis legalization has been also adopted by Uruguay and Canada at national level recently (Austen, 2017; Miroff, 2017) and considered in additions states in the US. The major provision of state laws in the US was to allow retail sale. By the end of 2018, Alaska, California, Colorado, Massachusetts, Nevada, Oregon, and Washington had opened their retail stores to adults aged 21 years or older (LawAtlas, 2019). The other legalizing states, with the only exceptions of Washington DC and Vermont, were planning to do so in the next 2–3 years.

Retail cannabis markets have expanded rapidly in the US. The number of licensed retail stores has grown nearly 400% in Colorado

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since retail markets opened in early 2014 (Orens, Light, Lewandowski, Rowberry, & Saloga, 2018). Annual retail sales in Colorado increased from $303 million in 2014 to $1213 million in 2018 (StateofColorado, 2019). In Washington, monthly retail sales reached $98 million two years after retail markets opened in July 2014 (Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017). Cannabis flowers have been dominating the retail markets, accounting for two thirds of the market share (Orens et al., 2018; Smart et al., 2017). Other types of cannabis products on legal markets include concentrates, cannabis-infused edibles and drinks, etc. In the US, flowers are primarily consumed by smoking, and smoking flowers is the most common method to consume cannabis. Over 92% recreational cannabis users and over 82% medical cannabis users reported that, when they used cannabis last time, they smoked cannabis flowers (Pacula, Jacobson, & Maksabedian, 2016).

Studies evaluating the impacts of recreational cannabis legalization were just emerging. Most of them used a dichotomous measure of legalization status to examine the changes before and after the legalization. The findings suggested that the legalization may be associated with increased cannabis use in some subpopulation or states but had no impacts on motor vehicle crashes or prescription opioid use in adults (Aydelotte et al., 2017; Cerda et al., 2017; Hansen, Miller, & Weber, 2019; Kerr, Bae, Phibbs, & Kern, 2017; Shi et al., 2019). There was a paucity of research on cannabis commercialization. One study in Denver, Colorado examined the density of cannabis retail stores and found its associations with cannabis-related crime rates (Freisthler, Gaidus, Tam, Ponicki, & Gruenewald, 2017). Another study in Colorado suggested an increasing trend of cannabis use among trauma patients following cannabis commercialization (Chung et al., 2019).

The lack of knowledge regarding how individuals make purchase decisions and what policies would be effective tools for reducing problem cannabis use significantly hinders evidence-based policymaking after cannabis is commercialized. Current regulatory frameworks were primarily based on lessons learned from tobacco and alcohol control (Pacula, Kilmer, Wagenaar, Chaloupka, & Caulkins, 2014), with little support from empirical evidence of policy effects. To fill the knowledge gap, in this study, we examined the following product characteristics that may have potential to modify cannabis purchase behaviors and inform policymaking (Kilmer, 2017; Pacula et al., 2014).

Potency

Tetrahydrocannabinol (THC) and cannabidiol (CBD) are the two major chemical compounds in cannabis. Almost all states with retail markets required that manufactured cannabis products should list both THC and CBD levels on package labels. THC is the primary psychoactive constituent. Because of its influences on certain physiological and pathophysiological processes, THC could generate intoxicating psychoactive effects but also have potential to relieve health conditions such as pain (Izzo, Borrelli, Capasso, Di Marzo, & Mechoulam, 2009). THC increased from 3.4% in 1993 to 8.8% in 2008 (Mehmedic et al., 2010) and increased more dramatically after cannabis was commercialized, from 16% to nearly 20% during 2014–2017 (Orens et al., 2018). CBD is the primary non-psychoactive constitute that partially offsets THC's psychoactive properties (Hall & Degenhardt, 2009). As CBD has no known intoxicating psychoactive effects, there have been increasing interests in its therapeutic application. Some beneficial effects have been suggested (Niesink & van Laar, 2013). In the US, 17 states have passed state-wide laws allowing for high CBD concentrates with minimal THC for the treatment of epilepsy or seizures (Procon.org, 2019).

Primarily due to the concern of accidental poisonings, most states with retail markets have set limits on THC in edible products. Currently no state limits THC in flowers. In 2016, Colorado proposed to limit all types of cannabis products to 15–16% THC but the initiative failed (Ingold, 2016). Little is known about the impacts of THC and CBD levels on consumers' preferences and whether the impacts differ between recreational and medical users.

Warning messages

Currently all states with retail markets require text warning messages displayed on cannabis packages but the information varies across states (ShatterLabels, 2017). Some messages remind consumers that cannabis is a Schedule I drug, some describe the health risks, such as impaired driving and drug dependence, and others include statements that cannabis is not approved by the FDA. Tobacco and alcohol researchers have studied the impacts of warning labels extensively. Health warning messages prevent smoking initiation and promote smoking cessation (Hammond, 2011) but have little effects on drinking behaviors (Wilkinson & Room, 2009). There is a dearth of research regarding consumers' responsiveness to different types of warning messages.

Price

Prices of cannabis products on retail markets vary considerably across and within states (Hunt & Pacula, 2017; Smart et al., 2017). States also adopt different approaches to levy taxes (Nevada, 2018; Oregon, 2017; Rough, 2017; TaxFoundation, 2017). Sales tax is the most common form, ranging from 6.25% in Massachusetts to 17% in Oregon. In addition to sales tax, Colorado, Massachusetts, Nevada, and Washington also impose excise tax, with Washington's tax rate being the highest (37%). California has a combination of 15% sales tax and $9.25 per ounce flat tax rate for flower products. Alaska is the only state with a single flat tax rate. Many states also allow local municipalities to levy local sales or excise tax. The different prices and taxes across and within states may lead to substantial variations in total costs faced by consumers. The literature on tobacco and alcohol control repeatedly suggest that higher prices deter initiation and reduce consumption (Elder et al., 2010; Wagenaar, Salois, & Komro, 2009; Wagenaar, Tobler, & Komro, 2010; Wilson et al., 2012). Previous research on cannabis relied on illicit market data (Gallet, 2014; Pacula & Lundberg, 2014) with only one exception (Smart et al., 2017). It remains unclear, given the large declines in production costs in legalizing states (Smart et al., 2017), the extent to which changes in price influence cannabis purchase behaviors.

This study aimed to identify the impacts of product attributes on individual preferences for cannabis products on legal retail markets in the US. Particularly, we aimed to 1) examine the impacts of THC, CBD, warning messages, and price on adults' preferences for cannabis flowers; 2) examine the heterogeneities of the preferences among subgroups. We focused on cannabis flowers as flowers are dominating the US retail markets.

Methods

Study design

We used a cross-sectional online survey with discrete choice experiments (DCEs) to simulate individual decisions on purchasing hypothetical cannabis products. DCE is a stated-preference approach widely used in health economics to ascertain the relative importance of product attributes to consumers (Clark, Determann, Petrou, Moro, & de Bekker-Grob, 2014; de Bekker-Grob, Ryan, & Gerard, 2012; Ryan & Gerard, 2003; Soekhai, de Bekker-Grob, Ellis, & Vass, 2019). Particularly, it has been increasingly adopted in research on tobacco and alcohol use (Helter & Boehler, 2016; Lockshin, Wade, d'Hauteville, & Perrouty, 2006; Pechey, Burge, Mentzakis, Suhrcke, & Marteau, 2014; Regmi, Kaphle, Timilsina, & Tuha, 2018), which are arguably comparable to cannabis use after cannabis is commercialized.

Compared to observational data from population surveys or administrative records, DCE has the following advantages. 1) It can

manipulate choice scenarios shown to the same individual such that within- and between- individual variations are enabled. In contrast, policy variations in observational data are typically limited and only available at macro level such as state and county. 2) Because of its hypothetical nature, DCE provides opportunities to examine potentially influential attributes or policies that are not yet available or implemented. 3) DCE can infer causality. By randomly varying choice scenarios shown to the same individual, we can ensure that the systematic differences in choices are solely attributable to the experimental manipulation. 4) Surveys along with DCEs provide rich individual information that are often not available in administrative records.

Study sample

A convenience sample of 2400 adults were recruited from a US online panel in October 2017. Maintained by a marketing company, the panel consists of millions of adult panelists who voluntarily participate in online surveys like the one in our study. To be eligible for this study, respondents must be at least 21 years old, passing the age limit for legal purchase of recreational cannabis in the US. Respondents also must be living in one of the 6 US states that had legalized recreational cannabis at the time of interview, including California, Colorado, Massachusetts, Nevada, Oregon, and Washington. These states represented 96% of total population in all the 9 jurisdictions in the US that had legalized recreational cannabis by the end of 2017.[1] The panelists' age and state information were held by the marketing company before this survey was conducted. Only those meeting the inclusion criteria received email invitations. The respondents were prevented from participating multiple times using digital identify technology. A series of measures were also implemented to improve data quality. For example, respondents who completed survey in less than 3 min were considered paying insufficient attention to questions and removed. We also removed those who failed attention check questions. Respondents redeemed monetary incentives through loyalty programs upon successful completion of the survey.

We recruited equal sample sizes of those who did not use cannabis in the past 12 months (cannabis nonusers, N = 1200) and those who used cannabis at least once in the past 12 months (cannabis users, N = 1200). These 2 samples might have differential responses to product attributes. The sample size of 1200 exceeded most published DCE studies as well as the minimum sample size (˜150) calculated using the recommended statistical procedures in de Bekker-Grob et al (de Bekker-Grob, Donkers, Jonker, & Stolk, 2015). After excluding 55 respondents with incomplete or inconsistent information, the study sample was reduced to 1186 nonusers and 1159 users.

Experiment design

The attributes and corresponding levels in the DCE design are illustrated in Table 1. We focused on 4 attributes: (1) THC level, (2) CBD level, (3) warning messages, and (4) price.

For each of the 4 product attributes, we varied attribute levels based on available information on products sold in the US. The THC levels (15%, 20%, and 30%) represented common low, medium, and high levels of THC in published online product menus (Weedmaps, 2018). Similarly, prices ($20, $35, $50, and $65) were selected as values from within quartile distributions on online product menus (Weedmaps, 2018) for cannabis flowers sold in 1/8th ounce units (roughly equivalent to 3.5 g or 5 joints), the most popular unit size on retail markets (Smart et al., 2017). In the case of CBD, 0.4% was the median level of products sold on market (Smart et al., 2017), and ranges around that (0% and 15% CBD) were selected to represent CBD free products and products with high CBD, respectively. The first warning message (none) represented the default current federal requirement for cannabis product labeling, which is none given the federal prohibition. The second warning message (text warning) represented the style currently required by Colorado and Washington. The third warning message (graphic warning on drugged driving) was a graphic image adopted by Colorado in a state-wide campaign in 2016 to highlight the legal consequence of drugged driving. The fourth warning message (FDA disapproval disclaimer) was a modified FDA disclaimer stressing the fact that cannabis products received no evaluation or approval from the FDA (FDA, 2017); a similar disclaimer is required in Massachusetts (ShatterLabels, 2017). Each alternative in DCE represented a unique hypothetical cannabis product with the 4 attributes varying in levels as described above.

The DCEs were designed in accordance with good practices recommended by the Task Force (Bridges et al., 2011). Sawtooth software was used to construct DCEs with a Balanced Overlap method and Blocked Fractional Factorial design (Jaynes, Wong, & Xu, 2016). We prohibited dominant alternatives (always desirable) that contained the combination of THC 30% and price $20 and dominated alternatives (always undesirable) that contained the combination of THC 15% and price $65. The total number of possible alternatives excluding dominant and dominated alternatives was 120.

It is recommended that DCE choice scenarios are limited to 8–16 to avoid cognitive burden (Reed Johnson et al., 2013). Respondents were therefore randomly assigned to 1 out of 6 versions of surveys, with each containing 12 randomly ordered DCE choice scenarios. Each choice scenario asked respondents to choose from 4 alternatives: opt-out or any of the 3 hypothetical cannabis alternatives. An example of choice scenario is presented in Figure S1. These 72 (12*6) unique choice scenarios resulted in a D-efficiency of 81.4% relative to the full factorial design that includes all possible choice scenarios.

To increase the quality of DCE responses, prior to DCE questions, we provided narrative information introducing the general context and purpose of the research. We explained that "marijuana is also called cannabis, weed, herb, pot, grass, etc.". Respondents were reminded that, despite the hypothetical nature of the questions, their responses are important to research and policymaking and honest responses are needed. The choice alternatives would be the only options they could get in each choice scenario; they could select "none" to opt out of selecting any cannabis alternatives; they should select an alternative based on its characteristics; they should consider only warning messages associated with the alternatives in a choice scenario and should not carry them to other scenarios. We briefly explained that THC and CBD were the primary psychoactive and non-psychoactive ingredients in cannabis, respectively. Even though respondents may have limited or even inaccurate pre-existing knowledge, detailed information and scientific evidence on health effects were not provided. The purpose was to simulate choices in the real world where consumers were not educated.

Online survey

In addition to DCE questions, the survey also asked about cannabis use history and pattern, other drug use, cannabis-related perceptions, and socioeconomic background. The entire survey took 15 min on average to complete. The Institutional Review Board at University of California San Diego approved the study.

Measures

The primary outcome was a dichotomous variable indicating whether an alternative was chosen in a choice scenario. Because a

[1] The other 3 jurisdictions that had legalized recreational cannabis by the end of 2017 but were not included in this study were Alaska, Maine, and Washington DC. After the survey was implemented, 3 additional states (Illinois, Michigan, and Vermont) also passed laws to legalize recreational cannabis.

Table 1
Cannabis Flower Product Attributes and Corresponding Levels.

Attributes	Levels
Tetrahydrocannabinol (THC) Level	1. 15% 2. 20% 3. 30%
Cannabidiol (CBD) Level	1. 0% (CBD free) 2. 0.4% 3. 15%
Warning Message	1. None 2. Text warning currently adopted by Washington and Colorado: There may be health risks associated with consumption of this product. Should not be used by women that are pregnant or breast feeding. For use only by adults twenty-one and older. Keep out of reach of children. Marijuana can impair concentration, coordination, and judgment. Do not operate a vehicle or machinery under the influence of this drug. **Warning**: This product has intoxicating effects and may be habit forming. Smoking is hazardous to your health. This product may be unlawful outside of your state. **Caution**: When eaten or swallowed, the intoxicating effects of this drug may be delayed by two or more hours. 3. Graphic warning on drugged driving:  4. FDA disapproval disclaimer: This product is not approved by the FDA to treat, cure, or prevent any disease.
Price	1. $20 2. $35 3. $50 4. $65

Notes: The dominant and dominated combinations ($20 and THC 30%, $65 and THC 15%) were prohibited from the discrete choice experiment.

respondent was randomly assigned to 12 choice scenarios, each including 3 cannabis alternatives and an opt-out option, the total number of alternatives for the primary outcome analysis was 56,928 for nonusers and 55,632 for users. To examine the characteristics of respondents who chose to opt-out in all the 12 assigned choice scenarios, we created a secondary outcome measure, also a dichotomous variable, indicating whether a respondent always opted out. The analysis of this secondary outcome was conducted at individual level.

For the 4 attribute variables (alternative-specific variables) that varied across choice alternatives, the levels of price were modeled as a continuous variable, whereas the levels of THC, CBD, and warning messages were dummy coded. The following respondents' socioeconomic characteristics were considered as case-specific variables that were constant across alternatives and scenarios for the same respondent: gender, age, race/ethnicity, education, household income, knowledge about cannabis, past-month cigarette smoking, past-month binge drinking (drinking 5 or more alcoholic drinks in a single occasion), and state of residence. Among past-year nonusers, we also created an indicator for never users and former users. Among past-year users, past-month regular cannabis use was defined as using cannabis for at least 20 days in the past month (i.e., almost daily use); we identified reason of use with the question: "when you used marijuana, was it primarily for medical reasons to treat or decrease symptoms of a health condition, or was it primarily for recreational reasons to get pleasure or satisfaction?" The answers categorized users into recreational users (primarily using for recreational reasons), medical users (primarily using for medical reasons), and dual users (using for both recreational and medical reasons).

Statistical analysis

Descriptive statistics were provided on individual characteristics and chosen alternatives. Nested logit regressions (Hensher, Rose, & Greene, 2015) on alternative-level observations were used to model choice selections. Nested logit model was preferred to multinomial logit model in this study because it relaxes the assumption of independence of irrelevant alternatives which requires that the probability of choosing between two choice alternatives is independent of the presence of an additional alternative in the choice scenario. Nested logit model relaxes this assumption by dividing the decision into two sequential steps: the first step chooses between opt-out and any cannabis products, then conditional on choosing any cannabis products, the second step chooses between three cannabis alternatives. Nested logit regressions are especially appropriate for the analysis of past-year nonusers, whose decision about opt-out is likely separate from the decision of choosing which cannabis product. They were commonly used in tobacco research to estimate nonsmokers' choices (Salloum et al., 2015; Shang, Huang, Chaloupka, & Emery, 2017). To account for multiple choice decisions made by the same respondent, standard errors were clustered at individual level.

We first conducted regressions among nonusers and users, respectively, then among nonusers by former use status and among users by reason of use. To formally detect heterogeneities across subsamples, we also interacted alternative-specific variables with subsample indicators in separate regressions. Among users, we also added interaction terms between THC and CBD to identify the most preferred combination of potency measures.

Based on nested logit models, we computed willingness-to-pay (WTP) and relative importance. WTP quantifies monetary values associated with the marginal change in product attribute from the reference level to another level (e.g., THC from 15% to 20%). It was calculated as dividing the coefficient of an attribute level of interest by the negative of the coefficient of the price attribute. To assess the relative importance of an attribute, we first calculated the range of estimated coefficient values (part-worth utilities) for the attribute, then divided it by the sum of all the attribute ranges (Czoli, Goniewicz, Islam, Kotnowski, & Hammond, 2016). A higher relative importance indicates a higher weight that respondents placed on a product attribute in cannabis purchase decisions.

Logistic regressions on individual-level observations were used to examine the associations between always-opt-out and individual characteristics.

Table 2
Descriptive Individual-level Characteristics (N = 2345).

Characteristics	Past-year Nonusers				Past-year Users				
		By Former Use				By Reason of Use			
	All Past-year Nonusers (N = 1186)	Never Users (N = 625)	Former Users (N = 561)	Between-group Test P Value	All Past-year Users (N = 1159)	Primarily Used for Recreational Reasons Only (N = 459)	Primarily Used for Medical Reason Only (N = 282)	Used for Both Recreational and Medical Reasons (N = 418)	Between-group Test P Value
Gender				.33					< .001
Male	32.04%	33.28%	30.66%		31.49%	37.91%	31.56%	24.40%	
Female	67.96%	66.72%	69.34%		68.51%	62.09%	68.44%	75.60%	
Age				< .001					.004
21-29	15.50%	18.08%	12.83%		34.43%	37.25%	28.01%	35.65%	
30-44	26.90%	28.96%	24.60%		37.01%	35.73%	35.46%	39.47%	
45-59	22.93%	18.08%	28.34%		17.00%	14.81%	20.57%	16.99%	
60+	34.57%	34.88%	34.22%		11.56%	12.20%	15.96%	7.89%	
Race/ethnicity				.029					.40
Non-Hispanic White	79.68%	77.12%	82.53%		74.46%	72.98%	75.53%	75.36%	
Hispanic	8.01%	8.00%	8.02%		12.51%	12.64%	10.28%	13.88%	
Non-Hispanic Black	2.28%	2.40%	2.14%		5.35%	5.66%	4.96%	5.26%	
Non-Hispanic other minority	10.03%	12.48%	7.31%		7.68%	8.71%	9.22%	5.50%	
Education				.40					.17
High school or less	15.35%	15.20%	15.51%		20.79%	19.17%	21.99%	21.77%	
Some college	24.37%	22.88%	26.02%		31.49%	29.41%	29.79%	34.93%	
College degree or more	60.29%	61.92%	58.47%		47.71%	51.42%	48.23%	43.30%	
Household income				.005					.039
< $25,000	14.59%	15.68%	13.37%		21.14%	16.78%	21.63%	25.60%	
$25,000- $50,000	19.22%	15.84%	22.99%		24.42%	23.75%	23.05%	26.08%	
$50,000-75,000	22.34%	24.00%	20.50%		20.28%	21.13%	19.50%	19.86%	
> $75,000	35.83%	34.88%	36.90%		30.63%	34.86%	31.91%	25.12%	
Did not answer	8.01%	9.60%	6.24%		3.54%	3.49%	3.90%	3.35%	
Ever used cannabis in lifetime				NA					NA
Yes	47.30%	0%	100%		100%	100%	100%	100%	
No	52.70%	100%	0%		0%	0%	0%	0%	
Past-month regular cannabis use				NA					< .001
Yes	NA	NA	NA		30.37%	16.12%	26.95%	48.33%	
No	NA	NA	NA		69.63%	83.88%	73.05%	51.67%	
Past-year cannabis users by reason of use				NA					NA
Recreational users	NA	NA	NA		39.60%	100%	0%	0%	
Medical users	NA	NA	NA		24.33%	0%	100%	0%	
Dual users	NA	NA	NA		36.07%	0%	0%	100%	
Knowledge about cannabis				< .001					< .001
Moderate to High	45.70%	37.76%	54.55%		78.34%	71.02%	79.79%	85.41%	
Low	54.30%	62.24%	45.45%		21.66%	28.98%	20.21%	14.59%	
Past-month smoking				< .001					< .001
Yes	11.13%	4.32%	18.72%		29.94%	25.71%	25.53%	37.56%	
No	88.87%	95.68%	81.28%		70.06%	74.29%	74.47%	62.44%	
Past-month binge drinking				< .001					< .001
Yes	14.17%	8.48%	20.50%		35.38%	40.96%	19.50%	39.95%	
No	85.83%	91.52%	79.50%		64.62%	59.04%	80.50%	60.05%	
State of residence				.45					.10
California	18.55%	20.64%	16.22%		19.84%	17.86%	24.47%	18.90%	
Colorado	16.61%	16.16%	17.11%		17.52%	17.21%	15.25%	19.38%	
Massachusetts	20.24%	20.16%	20.32%		14.84%	18.30%	13.12%	12.20%	
Nevada	9.78%	8.80%	10.87%		13.72%	14.38%	12.06%	14.11%	
Oregon	16.53%	16.32%	16.76%		17.17%	14.81%	19.50%	18.18%	
Washington	18.30%	17.92%	18.72%		16.91%	17.43%	15.60%	17.22%	

Results

Descriptive statistics of study sample and DCE responses

Table 2 presents descriptive statistics of individual-level characteristics. About 47% of nonusers reported former cannabis use. Among users, 30% used cannabis regularly in the past month; 40% were recreational users, 24% were medical users, and the remaining 36% were dual users. Significant differences were observed in most characteristics by former use status among nonusers and by reason of use among users. Table S1 reports demographic differences between our study sample and national sample from the 2016 National Survey on Drug Use and Health. Our sample had a greater proportion of females, non-Hispanic Whites, and college graduates in both nonusers and users.

Table 3
Nested Logit Models of Cannabis Flower Preference: Full Sample, by Past-year Use Status.

Attributes	Past-year Nonusers Coefficient Estimate (95% CI)	Past-year Users	Past-year Nonusers Willingness to Pay Estimate ($) (95% CI)	Past-year Users
Tetrahydrocannabinol (THC) Level, dichotomous				
15% (reference)				
20%	.016	.18***	1.24	4.88
	(-.0089, .041)	(.12, .24)	(-.60, 3.0)	(3.39, 6.37)
30%	.041*	.42***	3.10	11.57
	(.0030, .079)	(.33, .52)	(.35, 5.86)	(9.36, 13.79)
Cannabidiol (CBD) Level, dichotomous				
0% (reference)				
0.4%	.066***	.24***	5.02	6.49
	(.032, .10)	(.17, .31)	(2.82, 7.23)	(4.80, 8.17)
15%	.27***	.78***	21.08	21.11
	(.19, .35)	(.64, .93)	(17.29, 24.86)	(18.44, 23.79)
Warning Message, dichotomous				
None (reference)				
Text warning	−.0069	.079*	−.52	2.12
	(-.045, .031)	(.0083, .15)	(-3.44, 2.38)	(.19, 4.05)
Graphic warning on drugged driving	.050**	.040	3.82	1.08
	(.012, .088)	(-.030, .11)	(.99, 6.65)	(-.82, 2.98)
FDA disclaimer	−.040*	.011	−3.03	.29
	(-.080, -.00)	(-.053, .075)	(-5.95, -.12)	(-1.42, 2.01)
Price, continuous	−.013***	−.037***		
	(-.016, -.0096)	(-.042, -.031)		
Number of Respondents	1186	1159		
Number of Choice Scenarios	14,232	13,908		
Number of Choice Alternatives	56,928	55,632		

* $p < .05$.
** $p < .01$.
*** $p < .001$.

The descriptive statistics conditional on chosen alternatives are provided in Table S2. Among all choice scenarios presented to nonusers, roughly two thirds (63.44%) of the decisions were to opt out with a higher proportion in never users (75.11%) than former users (50.45%). In contrast, only 18.82% decisions were to opt out among past-year users. The patterns of attributes and levels in chosen alternatives were similar between subgroups. In general, selection of cannabis products increased with CBD level but decreased with THC level and price. The pattern by warning messages was not obvious.

Preferences among nonusers and users

Table 3 shows the results from nested logit regressions for cannabis nonusers and users, respectively. Compared to THC 15%, products with THC 20% and 30% were more likely to be chosen by users ($p < .001$), but only those with THC 30% were more likely to be chosen by nonusers ($p = .034$). Relative to CBD free, products with CBD 0.4% and 15% were more likely to be chosen by both nonusers and users ($p < .001$). Relative to no warning message, text warning was associated with a higher utility among users ($p = .028$) and graphic warning on drugged driving was associated with a higher utility among nonusers ($p = .010$); FDA disapproval disclaimer was associated with a lower utility among nonusers ($p = .050$). Products with high price were less likely to be chosen by both nonusers and users ($p < .001$). Results with interaction terms between attributes and past-year use indicator (Table S3) confirmed statistical differences in preferences between nonusers and users: compared to nonusers, users were more likely to choose products with higher THC, higher CBD, waring messages, and higher price ($p < .001$).

Preferences among nonusers by former use status and among users by reason of use

Table 4 reports subgroup analyses on cannabis nonusers by former use. Never users and former users both preferred higher CBD and lower price but were unresponsive to THC and text warning message. Never users were more likely to choose products with graphic warning on drugged driving ($p = .005$) and former users were less likely to choose products with FDA disapproval disclaimer ($p = .027$). Table S4 reports results with interaction terms between attributes and former use indicator. Compared to never users, former users were more likely to choose products with higher CBD, text warning, FDA disclaimer, and higher price. Preferences for THC and graphic warning did not differ between never users and former users.

Table 5 reports subgroup analyses on users by reason of use. All the three subgroups preferred higher CBD and lower price. Recreational and dual users also preferred higher THC ($p < .001$), but medical users were not responsive to THC. Regarding warning messages, medical users preferred text warning ($p = .005$), recreational users preferred graphic warning on drugged driving ($p = .049$). All the three subgroups were unresponsive to FDA disclaimer. Results with interaction terms between attributes and reason of use indicators (Table S5) confirmed statistical differences in preferences by reason of use. Compared to medical users, recreational users preferred products with higher THC, lower CBD, graphic warning, and lower price, whereas dual users preferred products with higher THC, higher CBD, graphic warning, FDA disclaimer, and lower price.

Table S6 reported results with THC and CBD interactions among users by reason of use. The most preferred combination was THC 30% and CBD 15% among recreational users and dual users, but medical users preferred THC 20%/CBD 15% combination and THC 15%/ CBD 15% combination more than THC 30%/CBD 15% combination.

Willingness to pay (WTP)

WTP estimates are reported in Tables 3–5. For example, among users, medical users had the highest WTP for higher CBD products ($14.54 more for CBD 0.4% and $47.79 more for CBD 15% relative to

Table 4
Nested Logit Models of Cannabis Flower Preference: Past-year Nonusers Only, by Former Use.

Attributes	Never Users Coefficient Estimate (95% CI)	Former Users	Never Users Willingness to Pay Estimate ($) (95% CI)	Former Users
Tetrahydrocannabinol (THC) Level, dichotomous				
15% (reference)				
20%	.020 (-.0072, .048)	.0073 (-.035, .049)	2.40 (-.32, 5.13)	.42 (-2.01, 2.86)
30%	.016 (-.018, .052)	.064 (-.00094, .12)	1.96 (-1.92, 5.85)	3.72 (.028, 7.41)
Cannabidiol (CBD) Level, dichotomous				
0% (reference)				
0.4%	.045* (.0093, .081)	.087** (.031, .14)	5.32 (1.78, 8.86)	5.06 (2.26, 7.87)
15%	.17*** (.070, .27)	.37*** (.25, .49)	19.98 (14.10, 25.87)	21.82 (16.90, 26.75)
Warning Message, dichotomous				
None (reference)				
Text warning	.021 (-.024, .067)	−.041 (-.10, .019)	2.53 (-2.74, 7.81)	−2.43 (-5.85, .99)
Graphic warning on drugged driving	.078** (.023, .13)	.012 (-.048, .072)	9.15 (4.45, 13.85)	.71 (-2.79, 4.22)
FDA disclaimer	−.010 (-.055, .034)	−.070* (-.13, -.0080)	−1.23 (-6.44, 3.96)	−4.11 (-7.58, -.64)
Price, continuous	−.0085*** (-.013, -.0037)	−.017*** (-.022, -.012)		
Number of Respondents	625	561		
Number of Choice Scenarios	7,500	6,732		
Number of Choice Alternatives	30,000	26,928		

* p < .05.
** p < .01.
*** p < .001.

Table 5
Nested Logit Models of Cannabis Flower Preference: Past-year Users Only, by Reason of Use.

Attributes	Recreational Cannabis Users Coefficient Estimate (95% CI)	Medical Cannabis Users	Dual Users	Recreational Cannabis Users Willingness to Pay Estimate ($) (95% CI)	Medical Cannabis Users	Dual Users
Tetrahydrocannabinol (THC) Level, continuous						
15% (reference)						
20%	.17*** (.081, .26)	.041 (-.12, .20)	.29*** (.17, .41)	4.82 (2.57, 7.07)	1.19 (-3.38, 5.77)	6.24 (4.07, 8.41)
30%	.37*** (.23, .51)	.15 (-.084, .38)	.70*** (.48, .91)	10.44 (7.08, 13.79)	4.32 (-2.47, 11.12)	15.05 (11.82, 18.29)
Cannabidiol (CBD) Level, dichotomous						
0% (reference)						
0.4%	.092* (.0093, .17)	.50*** (.25, .75)	.37*** (.23, .51)	2.59 (.38, 4.80)	14.54 (8.05, 21.03)	8.05 (5.52, 10.57)
15%	.36*** (.21, .50)	1.66*** (1.16, 2.16)	1.09*** (.81, 1.37)	10.09 (6.90, 13.28)	47.79 (36.43, 59.15)	23.45 (19.38, 27.52)
Warning Message, dichotomous						
None (reference)						
Text warning	−.0037 (-.10, .098)	.30** (.090, .52)	.079 (-.044, .20)	−.10 (-2.96, 2.76)	8.76 (2.07, 15.45)	1.70 (-.99, 4.40)
Graphic warning on drugged driving	.096*(.00021, .19)	−.0064 (-.23, .21)	−.022 (-.15, .10)	2.71 (-.035, 5.46)	−.18 (-6.62, 6.25)	−.48 (-3.21, 2.24)
FDA disclaimer	−.042 (-.13, .050)	.10 (-.090, .29)	.042 (-.074, .15)	−1.18 (-3.72, 1.35)	2.96 (-2.72, 8.65)	.90 (-1.61, 3.42)
Price, continuous	−.035*** (-.0446, -.026)	−.034*** (-.044, -.025)	−.046*** (-.057, -.035)			
Number of Respondents	459	282	418			
Number of Choice Scenarios	5,508	3,384	5,016			
Number of Choice Alternatives	22,032	13,536	20,064			

* p < .05.
** p < .01.
*** p < .001.

CBD free), and dual users had the highest WTP for higher THC products ($6.24 more for THC 20% and $15.05 more for THC 30% relative to THC 15%).

Relative importance

Figure S2 depicts the relative importance of product attributes. Overall, price accounted for over half of cannabis purchase decisions, followed by CBD (nearly 30%). The only exception was medical users, who perceived CBD as the most important attribute (47%) and price as the second most important attribute (41%).

Predictors of always opt-out

In Table S7, we assessed the predictors of always opt-out. A larger proportion of cannabis nonusers (53.88%) always opted out, while a considerably smaller share of cannabis users (7.85%) did so. Age and knowledge about cannabis were the two biggest drivers for opting out among both nonusers and users.

Discussion

This study examined the impacts of THC, CBD, warning messages, and price on individual preferences for legal cannabis flowers among US adults. The study fills important research gaps. It is the first study using DCEs to investigate cannabis product attributes that are important to consumers and policymakers. It is the first to examine heterogeneities in preferences for cannabis between nonusers and users and among users by reason of use.

The findings suggested that, recreational cannabis users and dual users preferred cannabis flowers with higher THC, but never users, former users, and medical cannabis users were not responsive to THC level. This is corroborated with clinical evidence that THC is the primary psychoactive constituent that gets people high (Hall & Degenhardt, 2009). Those who were not interested in getting high were therefore not influenced by THC. Regarding CBD, products with higher CBD were consistently more likely to be chosen by all types of respondents, regardless of their cannabis use history and reason of use. CBD is typically considered providing therapeutic effects without intoxication. Not surprisingly, medical users had the highest WTP for high CBD products and placed the highest relative weight to CBD.

The results on warning messages were mixed and most were counterintuitive. The only type of warning message that discouraged cannabis choice was FDA disapproval disclaimer, with significant effects only in former users. Text warning message was preferred among medical users. We were not able to provide empirical evidence to explain this finding. It is likely that the message was perceived by medical users as drug use instructions that endorse medical use rather than as warnings of health risks. Graphic warning had null associations among most subgroups but positive associations among never users and recreational users. It may be that individuals appropriately separated the decision to use any cannabis from the decision to drive impaired; the graphic may even draw their attention and promote product choice. Future research is warranted to validate the puzzling results in other DCEs or observational data. It is worth noting that the warning messages investigated in our study were very basic, similar to those used on alcohol packages which had little impacts on drinking behaviors (Wilkinson & Room, 2009). The findings should not be generalized to comprehensive and graphic warning messages that have been proven effective in tobacco control (Hammond, 2011).

Consistent with tobacco and alcohol research, products with a higher price were significantly less likely to be chosen in all subgroups. Price also accounted for approximately half of the decisions in all subgroups. Future research is encouraged to evaluate price effects on youth and effects of different tax forms.

This study has limitations. Respondents may have made hypothetical decisions that deviated from their choices in the real world. Studies have suggested satisfactory predictability of behavioral economics experiments on real-world health behaviors in general and drug use behaviors in particular (Olmstead, Alessi, Kline, Pacula, & Petry, 2015; Quaife, Terris-Prestholt, Di Tanna, & Vickerman, 2018), but there is still concern about the external validity of our DCE data. DCEs oversimplify the real world. Respondents typically had more options in the real world than those presented in hypothetical scenarios. Cannabis flowers still dominate the legal retail markets in the US (Schauer, King, Bunnell, Promoff, & McAfee, 2016; Smart et al., 2017), but other forms of cannabis such as concentrates and edibles have become increasingly popular (Schauer et al., 2016). We also ignored cannabis alternatives from illicit markets, which might be cheaper without taxes. Future studies should evaluate to what extent the decisions of cannabis purchase in DCEs could be replicated in the reality. Studies are also encouraged to examine alternative forms of cannabis and alternative sources of cannabis.

Another limitation of this study is the ambiguity of the opt-out option. Opting-out to select any cannabis products in the choice scenario may mean choosing not to consume cannabis at all or alternatively mean choosing cannabis from other sources including illicit market. The findings cannot be used to project the extensive margin (whether or not to consume cannabis) or intensive margin (how much cannabis to consume) of consumer behaviors in reality.

In our DCE design, different warning messages were attached to cannabis flowers with different characteristics in the same choice scenario. While this is a common practice in tobacco research (Regmi et al., 2018), respondents likely carried over the warning message in one choice alternative to another within the same choice scenario. For example, if one choice alterative carried drugged driving warning message and another carried FDA disapproval disclaimer, respondents may interpret that the two messages applied to both alternatives at the same time in the same choice scenario. To our knowledge, however, no studies have assessed how such design may impact the validity of DCE studies. We look forward to future research to address this concern.

Like other studies relying on online convenience panels, the study sample who self-selected to participate in the survey does not fully represent the study population of interest. To what extent the study findings could be generalized to the general population is unknown. Future research is encouraged to utilize representative samples. Furthermore, our findings may not be generalizable to other states that adopted recreational cannabis legalization later than this study. They may not be generalizable to other countries with legal cannabis markets (Uruguay and Canada) either, because these countries regulate retail sale with different approaches.

We were not able to examine the full range of attribute levels. For example, THC free products, which were rare on market, were not considered.

In the introduction of DCEs, respondents were instructed that $1/8^{th}$ ounce of cannabis flowers was roughly equivalent to 5 joints, as suggested by an empirical study (Mariani, Brooks, Haney, & Levin, 2011). Some users may use bigger or smaller joints in real life. This individual variation should not have influenced individual choices between different choice alternatives, as the $1/8^{th}$ ounce or 5 joints were invariant across alternatives and scenarios. However, we may have the endogeneity issue if respondents interpreted that the total THC and CBD intake were also varied with the amount of cannabis flowers they put in a joint. Whether this potential endogeneity issue influenced individual decisions is worth further investigations.

Finally, we restricted the study sample to adults aged 21 or older, who can legally purchase cannabis in retail outlets. Nonetheless, youth may have been increasingly exposed to cannabis after the states opened legal markets. The factors influencing their purchase decisions are likely different from adults. For example, they might be more responsive to price but less responsive to health benefits of cannabis. Future studies are encouraged to examine behaviors of younger

population.

Given the limitations, the findings derived from DCE hypothetical scenarios may not be directly extrapolated to the real-world setting. Nonetheless, knowing consumer preferences could still inform policy-making. Cannabis with high THC increased severity of dependence, impaired executive function and motor control, and increased risks of anxiety, depression, and psychosis (Di Forti et al., 2009; Freeman & Winstock, 2015; Hall & Degenhardt, 2009; Ramaekers et al., 2006; Volkow, Baler, Compton, & Weiss, 2014). Because medical users were not responsive to high THC in our study, policymakers could consider designing policies to restrict THC level. Such policies may have potential to discourage the consumption of high-THC products among recreational users and dual users without influencing medical cannabis use. Warning messages had mixed influences on cannabis purchase decisions. It is suggestive that the warning messages currently adopted by states might not have the expected preventive effects. The consistent effects of price provided support to taxation policies. Of course, whether these potential policy impacts can be realized in the real world need to be validated with observational data.

Conclusion

Our study suggested that, for adults in US states with recreational cannabis legalization, potency, warning messages, and price may have influences on their choices of flower products and the influences might differ across different types of consumers. While more research is needed to substantiate the findings in representative samples and observational data, these product attributes may deserve consideration for cannabis regulatory framework.

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Authors' contributions

YS conceived and designed the study, designed the discrete choice experiment, developed the survey, collected the data, analyzed the data, interpreted the findings, and wrote the draft of the manuscript.

YC participated in discrete choice experiment design, survey development, finding interpretation, and manuscript writing.

CS participated in finding interpretation and manuscript writing.

RP participated in discrete choice experiment design, survey development, finding interpretation, and manuscript writing.

All authors approved the final manuscript.

Declaration of Competing Interest

The authors declared no conflict of interest.

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Appendix A. Supplementary data

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