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Behavioral economic analysis of legal and illegal cannabis demand in Spanish young adults with hazardous and non-hazardous cannabis use

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ABSTRACT

Background: In October 2021, a legal framework that regulates cannabis for recreational purposes in Spain was proposed, but research on its potential impacts on cannabis use is currently limited. This study examined the reliability and discriminant validity of two Marijuana Purchase Tasks (MPTs) for measuring hypothetical legal and illegal cannabis demand, and to examine differences in demand of both commodities in young adults at hazardous vs. non-hazardous cannabis use risk levels.

Methods: A total of 171 Spanish young adults [$M_{age} = 19.82$ ($SD = 1.81$)] with past-month cannabis use participated in a cross-sectional study from September to November 2021. Two 27-item MPTs were used to estimate hypothetical demand for legal and illegal cannabis independently. The Cannabis Use Disorder Identification Test (CUDIT-R) was used to assess hazardous cannabis use and test for discriminant validity of the MPTs. Reliability analyses were conducted using Classical Test Theory (Cronbach's alpha) and Item Response Theory (Item Information Functions).

Results: The MPT was reliable for measuring legal ($\alpha = 0.94$) and illegal ($\alpha = 0.90$) cannabis demand. Breakpoint (price at which demand ceases), and P_{max} (price associated with maximum expenditure) were the most sensitive indicators to discriminate participants with different levels of the cannabis reinforcing trait. No significant differences between legal and illegal cannabis demand in the whole sample were observed, but hazardous vs. non-hazardous users showed higher legal and illegal demand, and decreased Breakpoint and P_{max} if cannabis were legal vs illegal.

Conclusion: The MPT exhibits robust psychometric validity and may be useful to inform on cannabis regulatory science in Spain.

1. Introduction

The increasing trends in prevalence of cannabis use, risky patterns of use, and tetrahydrocannabinol (THC) potency levels have accelerated in recent years in Europe (EMDDA, 2022; Manthey et al., 2021). Spain is amongst the top ten European countries with the highest prevalence rates of regular cannabis use (17.1 %), particularly in young adults (i.e., 18–25) (Government Delegation for the National Drugs Plan, 2022), and this is concerning as the risk of cannabis use disorder (CUD) sharply increases with monthly (8 %) and weekly (16.8 %) cannabis use (Robinson et al., 2022). Furthermore, using cannabis has a negative impact in numerous other areas in life, including academic performance, risk of psychosis, anxiety, depression, cognitive impairment, and violence (Dellazizzo et al., 2020; Lorenzetti et al., 2020; Meier et al., 2015).

Given the diversity in regulations and policies throughout the world, the landscape in cannabis research is rapidly changing and there is increasing interest in estimating the potential impacts of cannabis legalization across countries and population groups (Hammond et al., 2020, 2022; Ladegard & Bhatia, 2023; Laqueur et al., 2020; Okey et al., 2022; Wang & Wilson, 2022; Wang et al., 2022). Emerging adulthood represents a particular vulnerable period of life for CUD (Croker et al., 2023; Hayatbakhsh et al., 2009; Mennis et al., 2023) and, more generally, for poor mental health, especially other substance use disorders (Volkow et al., 2021), anxiety, depression (Barker et al., 2019), and psychosis (Moe & Breitborde, 2018).

Data from Uruguay, Canada, and several U.S. states suggest mixed

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effects on the incidence and prevalence of cannabis use post-legalization (Imtiaz et al., 2023; Rotermann, 2020; Turna et al., 2021). For example, among students aged 18–21 from Uruguay, there was a transitory increase in cannabis use for recreational purposes that decreased thereafter (Rivera-Aguirre et al., 2022). Most studies using US samples show increases in cannabis use onset and prevalence rates (Gali et al., 2021), especially in young adults (Kilmer et al., 2022; Mennis et al., 2023; O'Grady et al., 2022), but reports also exist in which there were no impacts on increasing rates (Leung et al., 2018).

A meta-analytic study on the effects of cannabis legalization (for recreational and medical purposes) in adolescents and young adults' cannabis use patterns (Melchior et al., 2019) showed mixed results in the patterns of cannabis use of youth. The legalization of cannabis for medicinal use (20 studies), assessed mostly in the US, did not produce consistent increases in past-12-month and 30-day use, with six studies reporting an absence of impact on demand, three reporting a decrease, and four reporting an increase.

The impact of public policies (e.g., cannabis decriminalization or legalization) can be informed using behavioral economics (BE), a discipline evolved from behavioral analysis and economics (Bickel et al., 2010). BE offers a contextualized description on individuals' decision making that considers the contexts where decisions are made (Matjasko et al., 2016) and two core concepts: immediacy (present versus future reinforcers) and demand (motivation for use of a specific substance) (Bickel et al., 2014). A third concept that is equally relevant but studied less is availability of alternative reinforcement (Acuff et al., 2023). Beyond this, it affords a useful methodological platform for estimating drug demand using demand curve analysis of data collected in natural drug use scenarios or under hypothetical ones, the latter being particularly helpful due to the ethical concerns of delivering drugs in experimental settings (Bush et al., 2023; Motschman et al., 2022; Reed et al., 2022; Zvorsky et al., 2019).

Drug purchase tasks, known as hypothetical purchase tasks, have been extensively used in US and Canada for modelling substance use demand curves and are valuable for clinical and experimental research (González-Roz et al., 2019; Hindocha et al., 2017; Martínez-Loredo et al., 2021; Strickland et al., 2019). More precisely, the Marijuana Purchase Task (MPT; Aston et al., 2020; Collins et al., 2014; González-Roz et al., 2023) allows for the collection of information on cannabis purchases (i.e., demand) at increasing prices (typically between $0-$100) and better comprehension of the mechanisms of drug use maintenance and drug use recovery processes (like abstinence) in different groups of the population (González-Roz et al., 2023). The MPT yields five indices, four are empirically observed: breakpoint (first price at which demand ceases), O_{max} (maximum consumption), P_{max} (price that maximizes demand), and intensity (demand at zero cost), and one, named elasticity (change in consumption by each change in unit price given the span of the curve and the intensity), which is derived from exponential/exponentiated equations (Aston et al., 2017; Gilroy et al., 2020; Gilroy et al., 2019; Koffarnus et al., 2015).

In terms of validity evidence, the MPT has sound psychometric properties in adult (Aston et al., 2015; Collins et al., 2014) and young adult samples (Aston & Meshesha, 2020; Yurasek et al., 2023). There is evidence that the MPT relates to all indicators of cannabis use, including frequency, quantity, and severity of cannabis use in both population groups (Aston et al., 2015; González-Roz et al., 2023; Strickland et al., 2019; Teeters et al., 2019; Vincent et al., 2017). Differences between adolescents and adults in cannabis demand have been reported by Borissova et al. (2022). Authors informed of higher demand (intensity) and lower sensitivity of demand to increasing costs (lower elasticity) in adolescents as compared to adults. Insights from these BE measures are important from a public health standpoint as they inform on both the unit price and the cost at which cannabis is suppressed. Cannabis purchasing tasks for estimating the impacts of decriminalization and legalization scenarios have been used mainly in US but not yet in Europe (Donnan et al., 2022). Cross-elasticity assessments on legal and contraband cannabis demand have also only been conducted in American (Amlung et al., 2019) and Canadian samples (Amlung & MacKillop, 2019). Both previous studies provided evidence regarding the substitutability of legal and illegal cannabis, with increasing costs of legal products (i.e., >$12/ gram) favoring consumption of illegal products.

Spain is amongst the countries that has decriminalized cannabis for personal cultivation and use. Recently, several parliamentary groups have proposed the legal framework that regularizes and decriminalizes the consumption of cannabis for recreational purposes. The initiative has had extensive media coverage and raised a public debate amongst civil society forums, policy and decision makers, researchers, and the general public (Isorna et al., 2022). The proposal has been retracted due to concerns regarding undesirable public health effects, including augmented cannabis and other drug use incidence, particularly in the youngest population. However, there are scant empirical data to inform discussions of the potential impacts of cannabis legalization in Spain.

From a public health standpoint, it is not only necessary to look at potential increased prevalence rates, but also appraise the differential impacts by population groups. For the first time in Spain, this study used BE to inform potential effects of cannabis legalization on cannabis demand (and in turn consumption) among young adults who use cannabis. Specifically, in a sample of individuals reporting active cannabis use, we had three aims: to test the MPT's validity and its reliability (i.e., internal consistency and item response theory properties) as an assessment; to estimate and compare legal and illegal cannabis demand; and to examine differences between hazardous and non-hazardous cannabis users for both legal and illicit cannabis demand. To accomplish these goals, we used both the Classical Test Theory (CTT) and Item Response Theory (IRT), the latter being a relatively recent approach in the addiction field that captures nuanced differences in measurement reliability according to different levels of the latent trait (i.e., herein cannabis reinforcing trait) (see as an example Atkins et al., 2021). Given precision is not uniform across the entire range of test scores, the combination of these two approaches is expected to add methodological accuracy through estimations of the tasks' reliability at different levels of the construct under measurement.

2. Material and methods

2.1. Participants and procedure

The study sample comprised 171 past-month cannabis users (see Table 1 for participants' descriptive characteristics) from a larger longitudinal study of young adults in three communities in Spain (The Balearic Islands, the Principality of Asturias, and Aragon). The recruitment was conducted at university colleges and vocational schools from September to November 2021. The coordinators of the participating university degrees and vocational school centers were contacted to ask for collaboration and disseminate the online battery assessment that took approximately 45 min to complete. Participants were surveyed both in person using tablets (Lenovo® Tab M7) and online. To verify sufficient effort and attention on the assessment, four attentional control items (e.g., for this question choose "sometimes") with four response options (i.e., hardly ever, sometimes, half of the times, most of the times, almost always) were included within the battery assessment. Participants were required to provide at least two out of four correct responses. Overall, 2,980 participants were initially recruited and completed the assessment battery. Based on the eligibility criteria, a total of 121 were discarded due to being aged 26 or over. An additional 22 failed attentional control checks, and 75 were duplicated cases. This left a total sample of 2,762 young adults. Of them, 171 self-reported at least one cannabis joint in the past month and provided data on cannabis demand. These participants passed all the attentional control items, except four cases who had 75 % correct responses (1 incorrect out of 4 attentional control checks).

All participants provided written informed consent prior to the

Table 1
Demographics and cannabis use characteristics.

Variables	Total (N = 171)	Non-Hazardous cannabis users (n = 74)	Hazardous cannabis users (n = 97)	Statistic (t/χ^2)	*p*
Age M(SD)	19.82(1.81)	19.74(1.74)	19.88(1.88)	0.474	0.636
N female sex (%)	91 (53.2 %)	41 (55.4 %)	50 (51.5 %)	0.120	0.729
N Academic year (%)					
1st year	61(35.7 %)	25 (33.8 %)	36 (37.1 %)	0.852	0.931
2nd year	66(38.6 %)	29 (39.2 %)	37 (38.1 %)		
3rd year	12(7.0 %)	5 (6.8 %)	7 (7.2 %)		
4th year	3(1.8 %)	2 (2.7 %)	1 (1.10 %)		
Vocational training	29(17.0 %)	13 (17.6 %)	16 (16.5 %)		
Weekly discretionary income (€) M (SD)	87.31(193.76)	100.07(228.79)	77.58(162.65)	0.751	0.454
Joints/month (range)	6–9 joints	3–5 joints	10–19 joints	7.590	**< 0.001**
Grams/week M(SD)	4.37(6.63)	2.24(4.93)	6(7.3)	3.812	**< 0.001**
N Cannabis mixed with tobacco (%)	136 (79.5 %)	50 (67.6 %)	86 (88.7 %)	10.213	**0.001**
N Past-month frequency of cannabis use (%)					
1–2 occasions	46 (26.9 %)	37 (50.0 %)	9 (9.3 %)	54.521	**< 0.001**
3 occasions	24 (14.0 %)	15 (20.3 %)	9 (9.3 %)		
Once a week	20 (11.7 %)	9 (12.2 %)	11 (11.3 %)		
Twice a week	22 (12.9 %)	5 (6.8 %)	17 (17.5 %)		
≥3 occasions/week	59 (34.5 %)	8 (10.8 %)	51 (52.6 %)		
CUDIT-R M(SD)	9.99(6.3)	4.5(1.89)	14.18(5.16)	15.350	**< 0.001**

Note. CUDIT-R = Cannabis Use Disorder Identification Test (CUDIT-R).

assessment. The protocol (#191CER21) was reviewed and accepted by the Ethics Committee of the University of the Balearic Islands.

2.2. Assessment measures

Participants provided information on sociodemographics (sex, age, academic year, and weekly discretionary income). Cannabis use measures included joints/month, grams/week, percentage of users of cannabis mixed with tobacco, past month-cannabis use frequency, and cannabis use severity as assessed by the Spanish version of the Cannabis Use Identification Test-revised (CUDIT-R; Adamson et al., 2010; Mezquita et al., 2022). The total CUDIT-R score was used to dichotomize participants based on the CUDIT threshold of 8 which is used as an indicator of potentially hazardous use (Adamson et al., 2010; Mezquita et al., 2022).

To assess cannabis demand, participants completed two independent tasks for legal and illegal cannabis. Generally, instructional sets were equivalent, with the exception that the legal version contained a description of the dispensary and THC characteristics in a potentially legal scenario (see Supplementary Table 1). Both tasks included several prices and price ranges that are common in the cannabis purchase literature (González-Roz et al., 2023). The task comprised of 27 items. Prices in both tasks ranged between €0-€20 (€0.05, €0.10, €0.15, €0.20, €0.25, €0.30, €0.35, €0.40, €0.45, €0.50, €0.60, €0.70, €0.80, €0.90, €1.00, €1.20, €1.40, €1.60, €1.80, €2.00, €4.00, €6.00, €8.00, €10.00, €15.00, €20.00). In the BE literature, purchase tasks have typically used trait-like or state-like scenarios, meaning the former asks on typical substance use situations, while the latter refers to transient fluctuations on demand linked to the exact moment when the participant is being assessed (Aston & Cassidy, 2019). Participants were asked to indicate the number of joints they would purchase for a week considering their current desire to use cannabis. The vignette instructional set included: 1) to consider they did not use cannabis before, 2) to consider their incomes and savings totaled the usual ones, 3) no other forms of cannabis were available, 3) all joints had to be used within the time interval, and 4) sharing and saving were not permitted.

2.3. Data analyses

2.3.1. Reliability analyses

Preliminary tests on the reliability of the MPTs were conducted given there are no precedents of MPT investigations in Spanish samples. Reliability analyses were performed using CT (Cronbach's alpha coefficient) and the IRT (information functions) using the lavaan R package (see Rosseel, 2012). A heuristic approach of the Continuous Response Model (CRM) was used as outlined by Zopluoglu (2020). In this approach, a CFA is built by first transforming the observed indicator values using the equation $Z = \ln(X/(k - X))$ where X is the observed value and k is the maximum possible value of the indicator.

IRT is a psychometric approach that establishes a link between the properties of items (herein demand indices) on an instrument (herein the MPT), the individuals responding to it and the underlying trait being measured (cannabis reinforcing trait) (Thomas, 2011). Therefore, its main advantage is the accuracy in the precision of reliability, as it provides different estimates (discrimination and difficulty parameters) of psychometric performance for people scoring in the tasks differently. Discrimination refers to the degree to which an item can differentiate between participants with different levels of the latent trait under measurement (i.e., cannabis reinforcing trait), and difficulty parameters describe the level of the latent trait at which the precision provided by each MPT index is maximized. Discrimination values range theoretically from -∞ to +∞, and discrimination values between 1 and 2 are deemed as adequate (Abdu Bichi & Talib, 2018), with higher values indicating superior performance in discriminating between individuals with low and high cannabis demand. Difficulty parameters typically range between -3 and $+3$. Negative values imply low difficulty (i.e., higher precision at lower demand levels) and indicate that MPT indices are more informative for lower versus higher levels of the cannabis reinforcing trait, whereas positive values imply a higher difficulty, indicating that they measure with higher precision the individuals endorsing higher versus lower levels of the trait (cannabis reinforcing trait). Difficulty values equal to 1 or above indicate difficult and very difficult items, respectively, values between -1.00 and < 1.00 suggest moderate difficulty, between $-2.00 < -1.00$ indicate easy items, and between $-0.300 < -2.00$ mean very easy items (Abdu Bichi & Talib, 2018).

2.3.2. Behavioral economic analyses of legal and illegal cannabis demand

Descriptive analyses were conducted to characterize the study sample and skewness and kurtosis were inspected in the demand variables to check for normality assumptions. Following quality standards, the MPT data was processed using the PThelper package in R® software (R Core Team, 2021). The data processing report from PThelper is provided in

Supplementary Material 2. The coding for the empirical calculations of the demand indicators can be consulted as well as it is freely available (Belisario et al., 2022). Quality control using the 3-criterion method proposed by Stein et al. (2015) was applied to remove non-systematic data. For the illegal MPT, one participant had a trend violation (i.e., did not exhibit a decelerating trend), and for the legal MPT, 3 participants had trend violations. Elasticity was calculated for N = 126 participants in the illegal MPT, and for N = 137 in the legal MPT, as elasticity cannot be calculated from those having zero-demand within either of the first two items of the MPT.

All MPT indicators (i.e., intensity, breakpoint, O_{max}, P_{max}, elasticity) are from observed values except for elasticity (α, i.e., the rate of change in maximum responding [see Gilroy et al., 2020]) which was derived from individually fit curves. The demand curve was fit using the Kofarnus et al. (2015) exponentiated equation, and a k-value of 2 was fixed for all data given it was deemed the best fit (via overall demand curve fit) for both illegal and legal MPT instruments. This k-value is in alignment with an empirically-derived k-value — which is 2.2 (legal) and 2.3 (illegal). Some authors (like Kaplan; see Kaplan et al., 2018) add 0.5 to this value arguing that the full range of demand isn't represented using this empirical calculation. Arguably, this would bring us closer to a k-value of 3 (which we tested for, and the fit was better — higher R^2 — with a k-value of 2).

Curve fitting was reported using R^2 values from first aggregating the data and calculating mean consumption at each price point. In addition, we have provided the median R^2 and range of R^2 values from each individually fit curve. Outlier management was applied at both the price level and the indicator level using winsorization which retains the order of outliers by replacing them with the next highest non-outlying value plus 1 unit (at the indicator level, a unit of one was defined as 1 except for elasticity, which was expressed as a unit of 0.001). A z-score of |3.99| was used as the threshold in both instances, meaning that prices/indicators exceeding the absolute z-score of 3.99 underwent winsorization. For all demand indices, log-10 transformations were chosen over square root transformations, as this transformation consistently improved skewness and kurtosis between both MPT types (to keep them on the same transformed scale) (see Supplementary Table 3). These transformations were used in the following instances: significance testing, Cronhach's α, measurement invariance models, but not Item Response Theory (IRT) since the equation to transform indicators to variable Z includes a natural log transformation. In calculating variable Z, zero values present in O_{max} and P_{max} were first changed to a small non-zero value of 0.001 to allow for the natural log transformation. For breakpoint and P_{max}, the maximums were set to the limits under the MPT. For Intensity, the maximum allowable value of 99 plus 1 was used as the maximum. For elasticity, the maximum was set to 2 (no one in either MPT reached this), and for O_{max}, which could theoretically have a maximum value of 98 * 27 (= €2646), was instead capped at 34 (33 + 1), as 33 was the highest value reached on either MPTs.

T-tests were performed to examine differences between legal and illegal demand in the whole sample and to compare the differences between hazardous and non-hazardous users in legal and illegal demand. In addition, a two-way ANOVA was used to determine whether there were main and interactive effects of MPT type (legal and illegal) and CUD risk levels (hazardous vs. non-hazardous) on cannabis demand. Also, given interaction effects are not always significant, especially if the relationship between groups is opposite (they cancel each other out), we examined the post-hoc estimated marginal means across these two groupings (hazardous and non-hazardous users). For the omnibus test we adopt a $p < 0.05$, with more stringent values ($p < 0.005$) (Benjamin et al., 2018) adopted for the post-hoc testing since we are hypothesizing about differences between the MPT type as well as differences in CUDIT category (hazard category).

3. Results

3.1. Reliability of the legal and illegal Marijuana Purchase tasks

Both MPTs generated orderly demand curves (see Fig. 1), with consumption decelerating as a function of price and exhibiting both inelastic and elastic phases. Model fit in both cases was good/excellent (individual R^2 median (IQR) = 0.91 (0.83–0.98) for legal MPT; individual R^2 median = 0.90 (0.84–0.96) for illegal MPT). Model fit from aggregated data was good, with R^2 values ranging between 0.91 and 0.97. Behavioral economic demand curves by study group (hazardous and non-hazardous users) are shown in Fig. 2.

As assessed by the CTT, the reliability of the MPTs was optimal for assessing both legal (α = 0.90) and illegal cannabis demand (α = 0.94), and across cannabis use severity groups [non-hazardous users: [(α legal MPT = 0.77; α illegal MPT = 0.91); hazardous users: (α legal MPT = 0.91; α illegal MPT = 0.94)]. The IRT analyses [see Fig. 3 (panel A) for legal demand and Fig. 3 (panel B) for illegal demand] informed of higher precision of elasticity and intensity at lower levels of the cannabis reinforcing trait (θ values around −3), and higher precision of breakpoint (θ values around +2), O_{max} and P_{max} (θ values around +3) at the highest levels of the cannabis reinforcing trait. Discrimination and difficulty parameters are shown in Table 2. For both MPTs, discrimination values were higher for breakpoint and P_{max}. All MPT indices, except intensity and elasticity, showed high difficulty meaning high values were more likely to be endorsed by those presenting higher levels of the cannabis reinforcing trait (see Table 2).

3.2. Legal and illegal cannabis demand

Considering the whole sample of past-month cannabis users, there were not statistically significant differences in demand for legal vs. illegal cannabis. Intensity of legal and illegal demand did not differ, reflecting on average 12 ($SEM = 12.08 \pm 1.89$) and 16 ($SEM = 16.08 \pm 2.33$) joints per day, respectively ($t(336) = 0.80$, $p = 0.426$). The price at which cannabis demand would be suppressed was similar for legal ($SEM = €3.75 \pm 0.41$) and illegal cannabis ($SEM = €3.80 \pm 0.38$) ($t(336) = 1.22$, $p = 0.225$). Maximum expenditure (O_{max}) and associated price (P_{max}) did not differ for legal (O_{max}: $SEM = 4.78 \pm 0.50$; P_{max}: $SEM = 2.18 \pm 0.27$) and illegal (O_{max}: $SEM = 5.86 \pm 0.58$; P_{max}: $SEM = 2.05 \pm 0.24$) demand ($t_{(Omax)}(336) = 1.67$, $p = 0.10$); $t_{(Pmax)}(336) = 1.28$, $p = 0.201$). Elasticity for legal and illegal cannabis were 0.14 ($SE = 0.03$) and 0.16 ($SE = 0.03$), respectively ($t(261) = 0.62$, $p = 0.53$).

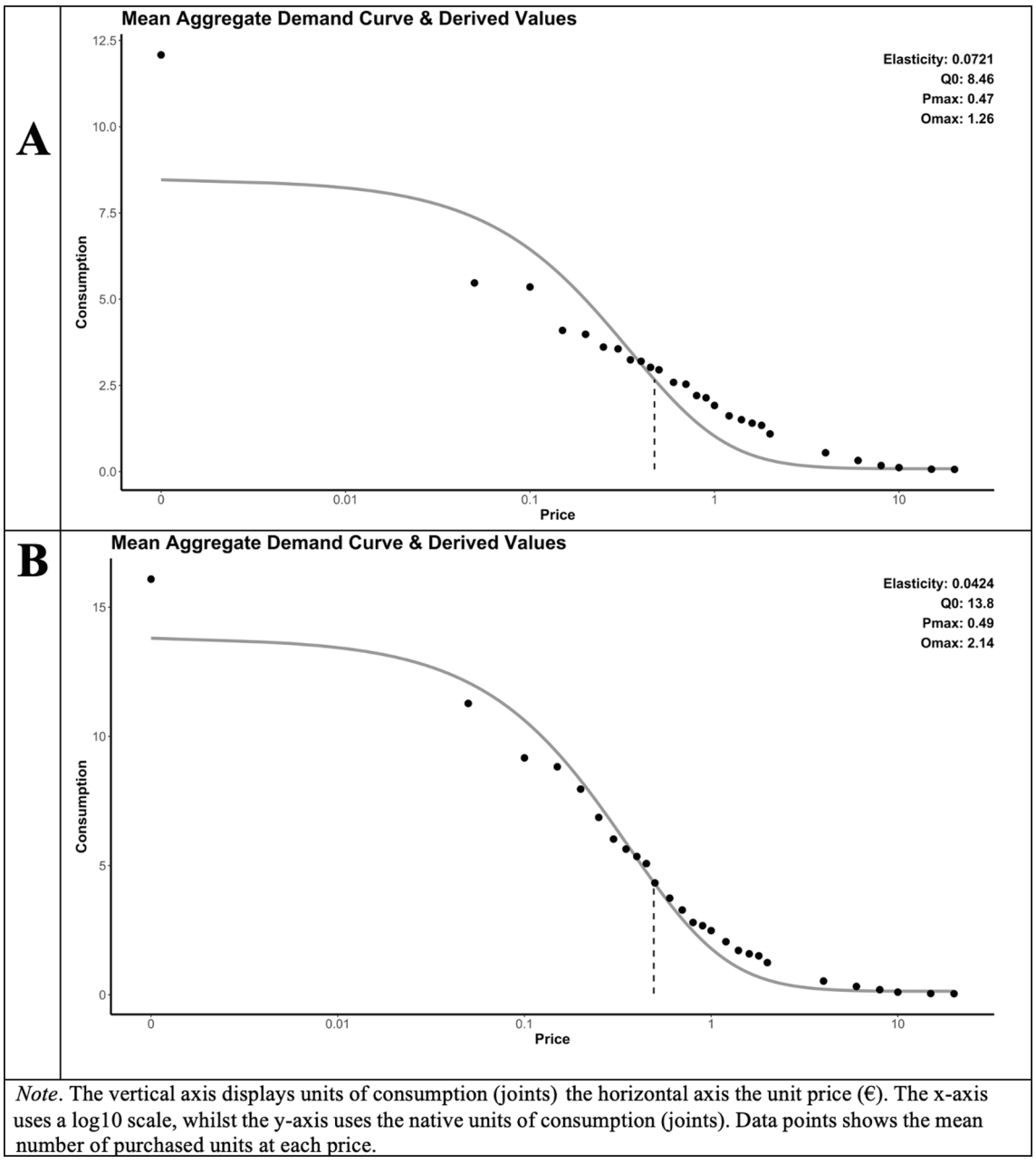
Hazardous cannabis users (n = 97; 56.7 %) showed significantly higher legal and illegal cannabis demand than non-hazardous users (CUDIT < 8; n = 74; 43.3 %) (see Table 3).

3.2.1. Main and interactive effects of commodity type (legal vs. illegal) and hazardous cannabis use risk level on demand

Results from the two-way repeat measures ANOVA revealed main significant effects of MPT type and CUD risk on cannabis demand (see Table 4), with no significant effects of covariates (i.e., age, sex, and weekly discretionary income) being observed (all p values > 0.05), and no significant interaction effects. Post-hoc testing revealed a significant difference between legal and illegal cannabis demand for those in the hazardous use category. Hazardous users showed higher Breakpoint and O_{max}, meaning they would consume significantly more if the cannabis were illegal than legal (see Table 5).

4. Discussion

This study used the MPT, a behavioral economic assessment of legal and illegal cannabis demand, in young adult cannabis users in Spain toward ascertaining the validity of the measure for informing policy questions on legalization. Several findings warrant emphasis. First, the



Note. The vertical axis displays units of consumption (joints) the horizontal axis the unit price (€). The x-axis uses a log10 scale, whilst the y-axis uses the native units of consumption (joints). Data points shows the mean number of purchased units at each price.

Fig. 1. Behavioral economic demand curves from the Marijuana Purchase Tasks (MPTs) (panel A: legal demand; panel B: illegal demand).

MPT exhibited robust psychometric properties overall and in terms of reliability for measuring both legal and illegal cannabis demand, a finding that maps well with prior research concluding adequate psychometric performance of purchase tasks (Athamneh et al., 2019; González-Roz et al., 2019, 2023; Kiselica et al., 2016; Martínez-Loredo et al., 2021; Yurasek et al., 2023; Zvorsky et al., 2019). Second, as suggested by the IRT difficulty parameters, breakpoint and P_{max} were amongst the most sensitive indicators to discriminate between participants with different levels of the cannabis reinforcing trait. Third, intensity and elasticity more reliably measured cannabis demand for people with lower levels of cannabis reinforcing efficacy, while the remaining indicators performed better for those presenting high levels of such trait. Fourth, relative to non-hazardous cannabis users, hazardous users showed higher demand for legal and illegal cannabis, and this group showed higher demand if the cannabis were illegal versus legal.

Of the demand indices, breakpoint and P_{max} performed the best in terms of mapping individuals along the continuum of the latent trait of cannabis reinforcing efficacy, and intensity and elasticity more precisely measured demand for those with low levels of the cannabis reinforcing trait. The superior performance in terms of discrimination observed for breakpoint and P_{max} may be related to the study sample. As most young populations are not economically independent yet, they are expected to be highly sensitive to increasing cost (Schultz et al., 2023). There is also evidence on higher breakpoint levels in co-users (Morris et al., 2018). In our study sample, virtually all participants were co-users of tobacco and cannabis, meaning persistence in consumption despite increasing costs would be a good proxy of CUD risk.

Intensity of demand is a proxy of consumption in unrestricted contexts and a longitudinal predictor of escalating cannabis use (Berey et al., 2022). The fact that cannabis is decriminalized in Spain might partially explain the superior precision for measuring demand observed for elasticity and intensity in those with low levels of cannabis demand, as they may be more sensitive to whatever costs may be (e.g., legal, and economic sanctions).

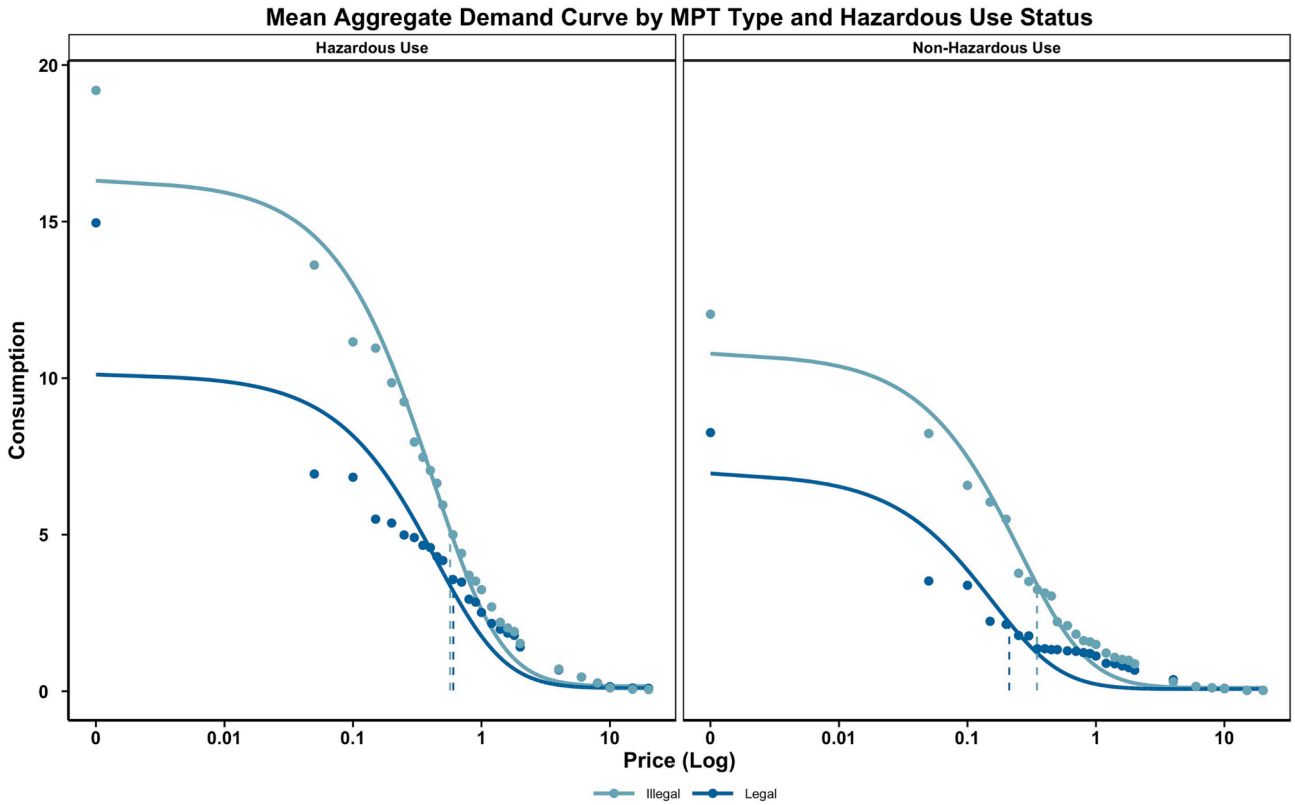


Fig. 2. Behavioral economic demand curves by study group (hazardous and non-hazardous users). Note. MPT = Marijuana Purchase Task.

Hazardous cannabis users showed higher demand for both legal and illegal cannabis than non-hazardous users, which has also been observed in US young adults (Yurasek et al., 2023). Individuals at high vs. low CUD risk present more frequent and intense use, craving, and coping motives, all factors relating to greater motivation to use cannabis and thus reinforcing effects (Enkema et al., 2020; Vedelago et al., 2022). Noteworthy, across groups, we did observe differences in cannabis demand, that is, hazardous users reported higher breakpoint and O_{max} in the illegal vs. legal scenario. Similarly, elasticity and P_{max} also had meaningful effect sizes that although did not meet the more stringent statistical significance level (i.e., $p < 0.005$ for the post-hoc tests) warrant future exploration. Several characteristics described in the legal vignette scenario may explain why hazardous users are not necessarily willing to buying more cannabis if it were legal. Regulated THC and CBD (i.e., no impurities and cutting with other drugs) may relate to lower cannabis use motivation (i.e., demand), given lower potency/effects may have been expected. Also, cannabis users refer to convenience of location as factors influencing cannabis consumption (Donnan et al., 2022), and there are reports by young populations on purchasing legally being less convenient as purchasing illegally (Robertson & Thyne, 2021). In this vein, it is possible that accessing cannabis through legal dispensaries rather than through street dealers deters cannabis use due to restricted store hours, limited quantity allowed per person, or lack of anonymity. Furthermore, young populations declare having a drug dealer in their neighborhood (D'Amico et al., 2020), and a sizeable number of young students inform of social supply (namely friends) as their primary purchasing sources (Bennett & Holloway, 2019), which indeed may work as a driver for cannabis use given it may represent loyalty to supplier, especially if the person is a friend. Relatedly, there is a traditional cannabis culture (rituals, symbols, and values) linked to recreational and illicit use in Spain, which may lead young people to think that the experience of taking cannabis in the context of an authorized seller differs from the experience of taking it on the illicit market (Sandberg, 2012).

In the context of no evidence of higher legal vs illegal cannabis demand, our study departs from prior BE studies that show legal cannabis is an effective substitute of illegal cannabis (Amlung & MacKillop, 2019; Amlung et al., 2019; Weinsztok et al., 2022). Notwithstanding, caution should be exerted, as legal and illegal cannabis demand were assessed independently in this study, and no conclusions on substitutability of legal cannabis can be made. Prior qualitative research revealed that young adult samples relate legalization to decreased de-stigmatization and increased acceptability of cannabis use, especially from relatives (Amroussia et al., 2020). Moreover, recent research has reported increased cannabis use among adolescents and young adults as a result of the legalization in those that perceive cannabis as less harmful (who tend to be hazardous users) (González-Roz et al., 2023; Mennis et al., 2023). Legalization is also related to perceiving that use is common among same-age peers, believing use is acceptable, easy access, and low perceived physical and psychological harm, all factors predicting increased cannabis use (Gilson et al., 2022). Beyond sociodemographic factors (age, sex, and weekly discretionary income were not significant covariates in the BE analyses), drivers for higher illegal vs. legal cannabis consumption has not been explored in the present study, and further investigation is warranted. In doing so, qualitative approaches might be insightful (Donnan et al., 2022).

Several limitations need to be acknowledged. First, the study comprised a sample of Spanish young adults from college and vocational school centers, and generalizability is restricted to these settings. Second, we examined hypothetical demand and purchases were somewhat high. Nonetheless, high correspondence between hypothetical cannabis demand and real-time report of cannabis use exists (Collins et al., 2014). Third, we used joints vs hits or grams and comparability across previous MPT studies is somewhat limited. Fourth, the MPT used was based on a single commodity assessment, and further research should look at the cross-commodity relationships between legal and illegal demand, and between recreational and medical cannabis. Prior studies have looked at the intersections between alternative and substitutability of reinforcers

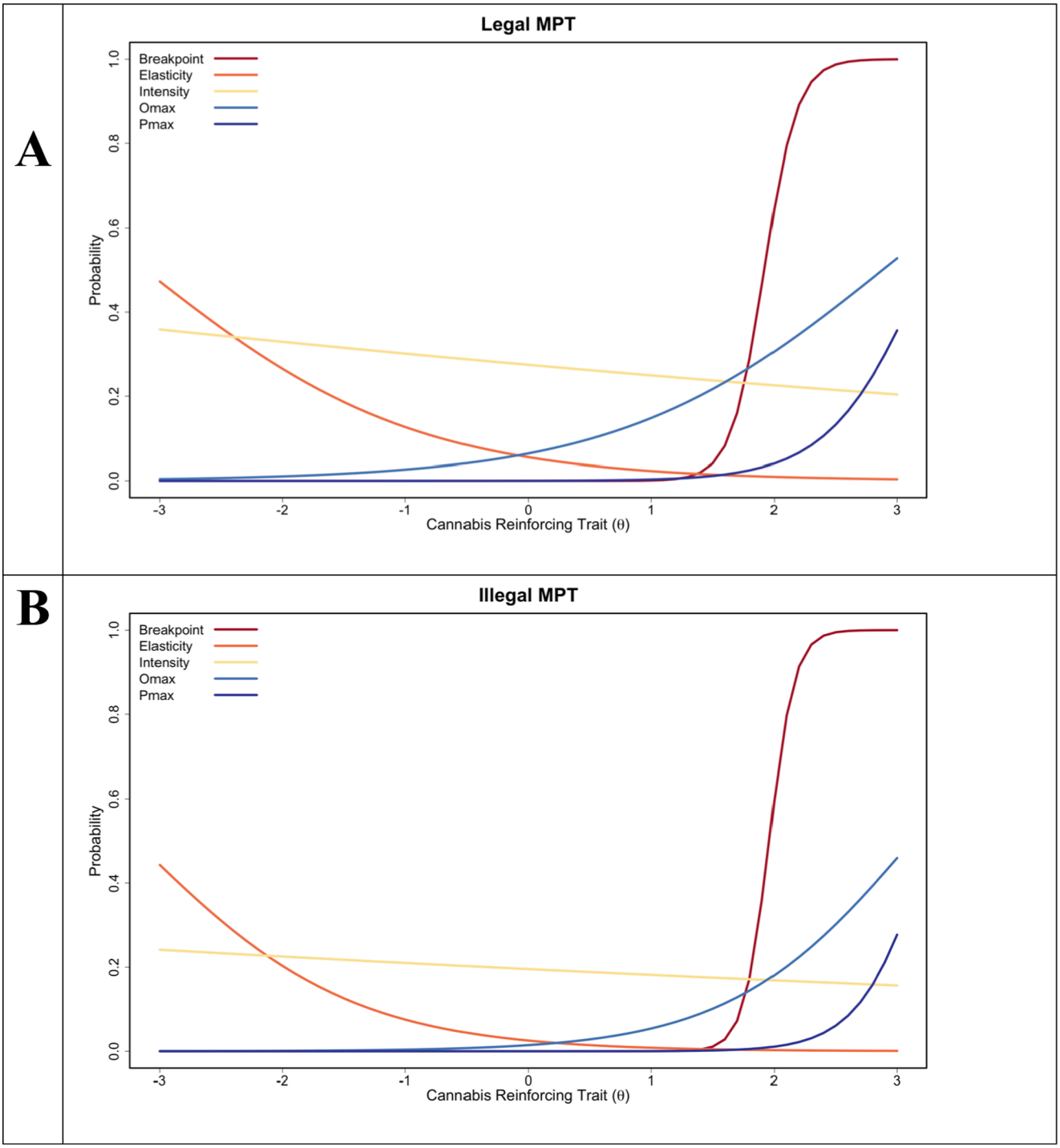


Fig. 3. Item information functions for the Marijuana Purchase Task (MPT) (panel A: legal demand; panel B: illegal demand). Note. Fig. 3 informs on the performance of the MPT indices and the probability of the demand indicators adequately capturing the latent demand trait. The y-axis is the probability of responding "correctly", meaning probability of responding with high demand when the individual does in fact have high demand in the latent (unobserved) reinforcing demand trait.

(Weinsztok et al., 2022), and this warrants further attention for regularizing cannabis products. Previous research, especially on tobacco (González-Roz et al., 2020; Mackillop et al., 2016; Weidberg et al., 2018), has found that purchase tasks have prognostic utility in treatment and there is a need for studies examining the MPT predictive validity in the context of prevention and treatment interventions.

This study provides new and valuable information on the potential impacts of cannabis legalization on cannabis demand among young adults in Spain. Findings supported the reliability of the MPT for assessing cannabis demand, which is relevant as it further provides evidence on the cross-cultural validity of the MPT. The demand indices (breakpoint, O_{max}, P_{max}) may be reliable for detecting participants at high CUD risk, while intensity and elasticity may stand as unique indicators of low CUD risk, suggesting the potential utility of these measures to detect individuals at risk of transitioning to higher levels. Given its relative brevity, it has the potential to be implemented in epidemiological surveys and inform public health measures. The use of an MPT could simulate an array of potential new policies and estimate their impacts on incidence, or use rates (Reed et al., 2022). It also has value for providing insight on the intention to use cannabis (incidence) under

Table 2
Discrimination (α) and difficulty (*b*) parameters.

	α (SE)	*b* (SE)
MPT legal		
Breakpoint	7.14 (0.45)	1.91 (0.1)
O_{max}	0.93 (0.1)	2.86 (0.23)
P_{max}	2.60 (0.18)	3.22 (0.18)
Intensity	−0.14 (0.09)	−7.25 (0.6)
Elasticity	−0.91 (0.1)	−3.09 (0.13)
MPT illegal		
Breakpoint	9.43 (0.6)	1.94 (0.11)
O_{max}	1.36 (0.12)	3.08 (0.22)
P_{max}	3.58 (0.24)	3.24 (0.18)
Intensity	−0.09 (0.09)	−15.45 (0.92)
Elasticity	−1.14 (0.12)	−3.17 (0.12)

Table 3
Legal and illegal cannabis demand in hazardous and non-hazardous cannabis users.

Mean ± SE:	Non-Hazardous Use (CUDIT < 8)	Hazardous Use (CUDIT ≥ 8)	*t*-test statistic; df; *p*-value
Breakpoint Legal	2.57 ± 0.51	4.64 ± 0.59	t = 3.06; df = 168; **p < 0.005**
Breakpoint Illegal	2.84 ± 0.51	4.54 ± 0.54	t = 3.63; df = 166; **p < 0.005**
Elasticity Legal	0.19 ± 0.05	0.11 ± 0.03	t = 2.29; df = 124; **p < 0.05**
Elasticity Illegal	0.29 ± 0.08	0.07 ± 0.02	t = 3.45; df = 135; **p < 0.005**
Intensity Legal	8.26 ± 2.40	14.96 ± 2.74	t = 3.99; df = 168; **p < 0.005**
Intensity Illegal	12.04 ± 3.06	19.19 ± 3.36	t = 3.43; df = 166; **p < 0.005**
O_{max} Legal	3.05 ± 0.6	6.09 ± 0.74	t = 3.15; df = 168; **p < 0.005**
O_{max} Illegal	3.63 ± 0.7	7.58 ± 0.82	t = 4.22; df = 166; **p < 0.005**
P_{max} Legal	1.64 ± 0.33	2.58 ± 0.4	t = 2.65; df = 168; **p < 0.01**
P_{max} Illegal	1.64 ± 0.32	2.36 ± 0.34	t = 3.24; df = 166; **p < 0.005**

Note. Bold numbers denote statistically significant differences emerged at a $p < 0.05$ level. Untransformed cannabis demand indices are provided for ease of interpretation. CUDIT-R = Cannabis Use Disorder Identification Test (CUDIT-R).

Table 4
Main and interactive effects between type of Marijuana Purchase Task and Cannabis Use Disorder Risk.

	Legal Status	Hazardous Use	Legal Status × Hazardous Use
Breakpoint	F = 10.32; **p < 0.005**	F = 12.65; **p < 0.005**	F = 0.50 p = 0.48
Elasticity	F = 2.59; p = 0.11	F = 13.17; **p < 0.005**	F = 1.25 p = 0.26
Intensity	F = 3.72; p = 0.06	F = 15.28; **p < 0.005**	F = 0.01 p = 0.92
O_{max}	F = 9.24; **p < 0.005**	F = 16.36; **p < 0.005**	F = 0.89 p = 0.35
P_{max}	F = 7.24; **p < 0.01**	F = 10.21; **p < 0.005**	F = 0.21 p = 0.64

Note. Statistically significant effects at a $p < 0.05$ level are denoted in bold.

Table 5
Post-hoc testing on differences between Marijuana Purchase Task (MPT) type by Cannabis Use Disorder Risk group.

	Hazardous Use Estimate ± SE (MPT type comparison[a])		Non-Hazardous Use Estimate ± SE (MPT type comparison[a])	
	Estimate ± SE (p-value)	Effect Size (Cohen's D)	Estimate ± SE (p-value)	Effect Size (Cohen's D)
Breakpoint	**0.15 ± 0.05 (p < 0.005)**	0.43	0.09 ± 0.05 (p = 0.10)	0.27
Elasticity	−0.08 ± 0.03 (p < 0.05)	−0.36	−0.01 ± 0.04 (p = 0.76)	−0.06
Intensity	0.05 ± 0.03 (p = 0.17)	0.20	0.05 ± 0.04 (p = 0.18)	0.22
O_{max}	**0.37 ± 0.12 (p < 0.005)**	0.43	0.19 ± 0.14 (p = 0.17)	0.23
P_{max}	0.24 ± 0.10 (p < 0.05)	0.34	0.16 ± 0.11 (p = 0.14)	0.24

Note. MPT = Marijuana Purchase Task. Statistically significant effects at a $p < 0.005$ level are denoted in bold.
[a] = difference of legal (subtracted) from illegal.

different scenarios (recreational or medical legalization) that are not yet in place.

Collectively, our findings suggest that having a legal cannabis alternative would not be expected to increase consumption uniformly across cannabis users based on the equivalence of reinforcing value of legal and illegal demand in the whole sample. Given higher demand was reported in the current scenario (decriminalization), results suggest demand would be significantly inelastic if legalization occurs, as illegal markets are not entirely supressed. Whether (or not) a legal alternative would shift demand from illegal to legal cannabis is still a matter of further examination in Spain. Relatedly, there is need to develop fulsome educational and regulatory frameworks deterring young adults and other vulnerable populations from cannabis misuse.

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CRediT authorship contribution statement

Alba González-Roz: Conceptualization, project administration, funding acquisition, and data collection, formal analyses, writing of the first draft, revised and edited the final draft. **Kyla Belisario:** participated in conceptualization, the writing of the first draft, formal analyses, revised and edited the final draft. **Roberto Secades-Villa:** Writing of the first draft, revised and edited the final draft. **José Muñiz:** Writing of the first draft, revised and edited the final draft. **James MacKillop:** Writing of the first draft, revised and edited the final draft. All authors have approved the final article.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [JM is a principal in Beam Diagnostics, Inc and has consulted to Clairvoyant Therapeutics, Inc.].

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.addbeh.2023.107878.

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