Prospective associations of behavioural economic demand for cannabis and alcohol with simultaneous cannabis and alcohol use among young adults

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Disclosures and Acknowledgements

Role of Funding Source: This research was supported by a grant from the Canadian Institutes of Health Research (159754; PIs: Jeffrey D. Wardell and Christian S. Hendershot). The views expressed herein do not represent the official policy of the Canadian Institutes of Health Research. Funding sources had no role in study design; the collection, analysis, and interpretation of data; the writing of the report; and in decision to submit the article for publication.

Contributors: SGC: conceptualization, data curation, formal analysis, visualization, writing – original draft; CHS: conceptualization, methodology, project administration, funding acquisition, writing – review & editing; JDW: conceptualization, methodology, project administration, funding acquisition, writing – review & editing, supervision. All authors have read and approved of the final manuscript.

Conflict of Interest: No conflict declared.

Acknowledgements: The authors wish to thank all members of the Behavioural Alcohol and Cannabis Research Lab at York University for their contributions to data collection for the study.

Author Note: Anonymized data, analysis code, and research materials are available upon request to the corresponding author, subject to any applicable ethics requirements. The study's design and its analysis were not pre-registered. Data for the analyses reported in this paper were drawn from a larger study of cannabis and alcohol co-use; data from the larger study have been included in one prior manuscript (Coelho et al., 2023) and two posters presented at the Annual Meeting of Research Society on Marijuana, all of which focused on different variables from the larger study and answered unrelated research questions.

Abstract

Behavioural economic demand for cannabis and alcohol is robustly associated with cannabis use and alcohol use, respectively. However, few studies have examined the contributions of cannabis and alcohol demand to simultaneous cannabis and alcohol use, which is common among young adults. We examined prospective associations of cannabis demand and alcohol demand with propensity for simultaneous use (broadly defined as using both cannabis and alcohol in the same day) and with cannabis and alcohol consumption during simultaneous use days among young adults. Young adults reporting simultaneous use (N=107) completed a Marijuana Purchase Task assessing cannabis demand and an Alcohol Purchase Task assessing alcohol demand. They then completed daily smartphone surveys over 21 days assessing cannabis and alcohol use. Multilevel models revealed that higher cannabis demand (i.e., higher O_{max}, P_{max}, and intensity; lower elasticity) was uniquely associated with greater propensity for simultaneous use relative to non-use. In addition, higher alcohol demand (lower elasticity) was uniquely associated with greater propensity for simultaneous use relative to cannabis-only use, and higher cannabis demand (higher breakpoint and intensity; lower elasticity) was uniquely associated with greater propensity for simultaneous use relative to alcohol-only use. Further, in models limited to simultaneous use days, greater cannabis demand (higher O_{max}, lower elasticity) and lower alcohol demand (higher elasticity) were uniquely associated with greater overall cannabis flower consumption, and higher alcohol demand (higher O_{max}, lower elasticity) was uniquely associated with greater overall alcohol consumption. Results suggest that individual differences in cannabis and alcohol demand may contribute to simultaneous cannabis and alcohol use behaviours in a substance-specific pattern. Further, cannabis demand may more strongly drive the tendency to engage in simultaneous use (versus non-use) relative to alcohol demand.

Keywords: Co-use; concurrent use; simultaneous use; simultaneous alcohol and marijuana (SAM) use; behavioural economics; demand; hypothetical purchase tasks; ecological momentary assessment

Public Health Significance Statement

This study observed contributions of individual differences in behavioural economic demand for cannabis and alcohol to simultaneous cannabis and alcohol use behaviours among young adults. Associations of demand with simultaneous use behaviours were generally substance-specific, although cannabis demand may more strongly drive the tendency to engage in use cannabis and alcohol simultaneously (versus to not use either substance) relative to alcohol demand. Results suggest that cannabis demand and alcohol demand may be important in understanding simultaneous use behaviours and should be examined in future research as potential targets of harm reduction interventions for simultaneous use among young adults.

Introduction

Cannabis-alcohol co-use (herein called co-use) has grown increasingly prevalent among young adults (Lee et al., 2022; McCabe et al., 2021; Patrick et al., 2019) and is broadly defined as using both alcohol and cannabis. Co-use encompasses both *concurrent use* and *simultaneous use* (Subbaraman & Kerr, 2015), the former describing the use of both cannabis and alcohol within a broad time period (e.g., month) and without overlapping effects. By contrast, simultaneous use has been variously defined and often describes using cannabis and alcohol at the same time or with overlapping effects, although has also been more broadly operationalized as same-day co-use (see Lee et al., 2022 for a review). In support of the latter operationalization of simultaneous use, recent data suggest that young adults' same-day co-use largely consists of closely proximal (i.e., within four hours) cannabis and alcohol use (Sokolovsky et al., 2020). Importantly, simultaneous use, relative to single-substance use, is associated with elevated risk for acute and chronic substance-related harms (Lee et al., 2022; Subbaraman & Kerr, 2015; Yurasek et al., 2017). Thus, understanding predictors of simultaneous use is critical for informing prevention and intervention efforts.

In combining psychology and economic principles to explain substance-use-related choice behaviour (Bickel et al., 2007, 2014), behavioural economics may provide a useful framework for improving understanding of simultaneous use behaviours. Behavioural economic models of substance use emphasize the relative reinforcing value of a substance as a key proximal determinant of its use (Bickel et al., 2014), indicated by behavioural economic demand for the substance (i.e., the quantitative relationship between its price and consumption; Bickel et al., 2007, 2014). Typically, cannabis and alcohol demand are assessed using the Marijuana Purchase Task (Aston et al., 2015; Collins et al., 2014) and Alcohol Purchase Task (Murphy &

MacKillop, 2006), respectively. In each of these tasks, participants report hypothetical consumption of the substance at increasing prices, from which five related indices of demand can be obtained: $O_{\max}$ (i.e., maximum expenditure), $P_{\max}$ (i.e., price corresponding to maximum expenditure), intensity (i.e., consumption at zero price), breakpoint (i.e., price at which consumption is supressed to zero), and elasticity (i.e., sensitivity of consumption to price, with lower elasticity indicating greater demand) (Aston et al., 2015; Collins et al., 2014; Murphy & MacKillop, 2006).

Cannabis and alcohol demand indices exhibit robust associations with quantity of use, frequency of use, and problematic use of cannabis and alcohol, respectively (Aston et al., 2015; Aston & Berey, 2022; González-Roz et al., 2022; Kiselica et al., 2016; Martínez-Loredo et al., 2021; Minhas et al., 2021; Strickland et al., 2017; Zvorsky et al., 2019), including prospectively (Acuff, Belisario, et al., 2023; Aston et al., 2023). However, relatively few studies have examined the roles of cannabis and alcohol demand in simultaneous use. Select studies have shown that adults who use both cannabis and alcohol exhibit higher alcohol demand on the APT relative to those who exclusively use alcohol (Morris et al., 2018; Naudé et al., 2021). Further, recent research using a cross-commodity purchase task observed complementarity between cannabis and alcohol demand among adults reporting past-month use of both cannabis and alcohol, such that increasing the price of one substance decreased consumption of both substances (Dolan et al., 2022). This study also found that participants exhibiting greater complementarity in demand for cannabis and alcohol reported more frequent simultaneous use (Dolan et al., 2022). Although these studies offer preliminary support for associations of alcohol and cannabis demand with co-use, including simultaneous use, methods vary across studies, and it is not yet clear whether cannabis and alcohol demand indices as traditionally assessed (i.e., for each substance independently) uniquely predict simultaneous use behaviours.

Given that cannabis demand is associated with cannabis use and alcohol demand is associated with alcohol use, it is possible that cannabis and alcohol demand may have substance-specific, additive influences on simultaneous use behaviour. For example, simultaneous use may be more frequent among those who show elevated demand for *both* cannabis and alcohol, such that demand for each substance is associated with significant, unique variance in simultaneous use. Further, of particular interest is whether cannabis and alcohol demand tap into a general hypersensitivity to reward, each influencing both cannabis- and alcohol-related simultaneous use behaviours, or whether their associations with simultaneous use behaviours are substance-specific. In the latter case, when holding cannabis demand constant, individuals with higher alcohol demand may report more frequently simultaneously using alcohol with cannabis relative to using cannabis alone. Likewise, when holding alcohol demand constant, individuals with higher cannabis demand may report more frequently simultaneously using cannabis with alcohol relative to using alcohol alone. Findings of one study support substance-specificity in associations of cannabis demand with cannabis use, showing that controlling for alcohol demand, cannabis demand was uniquely associated with weekly cannabis consumption, cannabis use frequency, and number of cannabis use disorder symptoms among adults reporting recent cannabis use (Strickland et al., 2017). However, no studies to our knowledge have examined the unique contributions of cannabis and alcohol demand to simultaneous use behaviour (i.e., the independent relationship between demand for one substance and simultaneous use while controlling for demand for the other substance) among people reporting simultaneous use.

Importantly, prior studies have rarely captured the role of demand in simultaneous use, and rather have predominantly focused on comparisons between people reporting use of both cannabis and alcohol within a broad time period (e.g., six months) and people reporting exclusive use of alcohol (Morris et al., 2018; Naudé et al., 2021). Only one prior study assessed simultaneous use, defined as same-day co-use, in relation to demand, (Dolan et al., 2022); however past-30-day simultaneous use frequency was assessed retrospectively, introducing potential recall biases. Thus, research accurately capturing day-level patterns of simultaneous use linked to individual differences in cannabis and alcohol demand is needed. Further, as prior work suggests considerable heterogeneity in alcohol and cannabis use behaviours among people who use each substance (Waddell, 2021), research capturing day-level patterns of simultaneous use is needed to determine whether demand predicts specific simultaneous use behaviours such as frequency of simultaneous use and quantities of each substance consumed during simultaneous use events.

Intensive longitudinal methods, including ecological momentary assessment (EMA) and daily diary methods, may address limitations in prior assessments of simultaneous use behaviours. In assessing cannabis and alcohol use at frequent (e.g., daily) intervals, intensive longitudinal methods permit more reliable assessment of simultaneous use. As well, through repeatedly assessing individuals' cannabis use and alcohol use, intensive longitudinal methods can capture individual differences in frequency of simultaneous use versus single-substance use and provide more reliable assessments of amounts of cannabis and alcohol consumed when simultaneously used, facilitating more detailed examinations of the role of demand in specific simultaneous use behaviours. Of importance to the current study, intensive longitudinal methods may be especially useful within prospective designs, permitting an examination of whether individual differences in cannabis and alcohol demand predict future simultaneous use behaviours to help establish temporality between demand and simultaneous use.

To this end, the current study used daily surveys to examine whether baseline individual differences in behavioural economic demand for each of cannabis and alcohol were prospectively associated with individual differences in frequency of simultaneous use relative to cannabis-only use, alcohol-only use, and non-use among young adults reporting simultaneous use. We also examined whether individual differences in cannabis and alcohol demand were associated with average quantities of cannabis consumption and alcohol consumption on days involving simultaneous use. We broadly defined simultaneous use as same-day cannabis-alcohol co-use. We hypothesized that higher alcohol demand would be associated with more frequent simultaneous use relative to cannabis-only use (controlling for cannabis demand), and that higher cannabis demand would be associated with more frequent simultaneous use relative to alcohol-only use (controlling for alcohol demand). We also expected that higher cannabis and alcohol demand would each be uniquely associated with more frequent simultaneous use relative to non-use. Further, we expected that higher cannabis demand would be uniquely associated with greater cannabis consumption on simultaneous use days, and that higher alcohol demand would be uniquely associated with greater alcohol consumption on simultaneous use days.

Method

Participants and recruitment

Data were drawn from a larger EMA study (Wardell et al., under review) examining simultaneous use among young adults. Participants were recruited from across Ontario, Canada via social media posts, online ads, and fliers posted on campuses and in the community. Eligible participants were 19–25 years old, used both alcohol and cannabis at least once per week on average during the past month, used cannabis and alcohol at the same time at least twice during the past month, and had a compatible smartphone (Android or iOS). Exclusion criteria were monthly use of substances other than cannabis, alcohol, or nicotine; current treatment for (or efforts to limit) cannabis or alcohol use; severe mental illness (e.g., psychosis, mania) or neurodevelopmental disorder; or exclusively medical use of cannabis. 177 young adults enrolled in the study, of whom nine were deemed ineligible prior to beginning the EMA protocol, and 17 were withdrawn due to completing less than 10% of the prompted EMA surveys, resulting in a sample of N=151. The N=107[1] participants who provided valid cannabis and alcohol demand data (see Data Analysis) comprised the analytic sample for the current study (see Table 1 for sample characteristics).

Procedures and measures

All study procedures were approved by the Research Ethics Board at York University (protocol #2021-158) and all participants provided informed consent.

Baseline assessment

Eligible participants attended a one-on-one baseline visit with a research assistant, during which they provided informed consent and were oriented to the EMA protocol and mobile application (MetricWire Inc., Waterloo, ON). Visual examples were used to train participants to accurately report quantities of cannabis flower consumed in grams and alcohol consumed in standard drinks. Subsequently, participants completed an online questionnaire, which included the MPT, the APT, and other cannabis- and alcohol-related measures used to characterize the sample in the current study. Participants received $40 CAD following the baseline assessment.

Baseline measures

[1] Data from one participant were not available for the current analysis due to a technical issue.

Cannabis and alcohol use and harms. The eight-item Cannabis Use Disorder Identification Test – Revised (CUDIT-R) (Adamson et al., 2010) and the 10-item Alcohol Use Disorder Identification Test (AUDIT) (Saunders et al., 1993) were administered to characterize levels of hazardous cannabis use and alcohol use, respectively. The CUDIT-R and the AUDIT have each been shown to be reliable and valid in assessing hazardous cannabis use and alcohol use, respectively, among young adults (Coelho et al., 2024; Meneses-Gaya et al., 2009; Schultz et al., 2019; Toner et al., 2019), and exhibited acceptable internal consistent in our sample (CUDIT-R: $\alpha = 0.77$, $\omega = 0.80$; AUDIT: $\alpha = 0.75$, $\omega = 0.77$). Participants also completed the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU) (Cuttler & Spradlin, 2017), which has been psychometrically validated among young adults (Gette et al., 2023). The DFAQ-CU included items assessing typical frequency of cannabis use and grams of cannabis flower used per typical session, day, and week. In addition, participants completed items from the National Institute on Alcohol Abuse and Alcoholism (NIAAA) Recommended Alcohol Screening Questions (NIAAA Task Force on Recommended Questions, 2003) assessing past-year alcohol use frequency, drinks consumed on a typical drinking day, largest number of drinks consumed in a day, and heavy episodic drinking frequency.

Cannabis demand. A modified version of the MPT (Aston et al., 2021), describing a hypothetical cannabis purchasing scenario, was used to assess behavioural economic demand for cannabis. The MPT has been shown to be reliable and valid, including in young adult samples (Aston & Meshesha, 2020; González-Roz et al., 2022). Participants reported how many grams of dried cannabis flower or leaf they would consume over a typical week at 20 different price points, ranging from “free” to “$60 per gram.” In the current study, we asked participants to round to the nearest gram and responses were capped at 28 grams to avoid extreme outliers. We used instructions from Amlung & MacKillop (2019), which outlined several assumptions, including that the cannabis was exclusively for personal use, all cannabis had to be used within the week, no other cannabis or other drugs could be used or purchased outside of the purchasing scenario, and cannabis would be of similar quality and strength to that typically used. Complete instructions are presented in the supplemental materials.

Alcohol demand. The APT (Murphy & MacKillop, 2006) was used to assess behavioural economic demand for cannabis. Several studies have supported the reliability and validity of the APT, including among young adults (Kiselica et al., 2016; Martínez-Loredo et al., 2021; Murphy et al., 2009). Participants reported how many standard drinks they would consume during a typical five-hour period at a party at 16 different price points, ranging from “free” to “$20 per drink.” Participants were asked to round to the nearest standard drink, and responses were capped at 50 drinks to avoid extreme outliers. Instructions were from Murphy and MacKillop (2006) and outlined several assumptions, including that the alcohol was exclusively for personal use, the alcohol had to be used within the five-hour period, no alcohol or drug use were to occur before or after the party, and no other alcohol could be brought to the party (see supplemental materials).

EMA assessment

The 21-day EMA protocol began the day after the baseline assessment and involved daily, randomly-timed, and event-contingent surveys; only daily surveys were used in the current analysis as they most comprehensively assessed daily alcohol and cannabis consumption. Daily surveys were available each day from 7:00 AM until 1:00 PM, and several reminder notifications were sent leading up to survey expiry. In each survey, participants reported whether they had used cannabis during the previous day, and if so, the form(s) of cannabis used (flower, concentrates, edibles/beverages, other), route(s) of cannabis administration (smoked, vaporized, ate/drank, other), and grams of cannabis flower used (if applicable). Cannabis-related daily survey items were drawn from the DFAQ-CU (Cuttler & Spradlin, 2017) and were modified to inquire about cannabis use during the previous day (e.g., "*How much total marijuana did you personally use yesterday (not including concentrates and edibles) in grams?"*) rather typical patterns of cannabis use. Participants also reported whether they used alcohol during the previous day, and if so, the number of standard drinks they consumed. Further, on days when they reported using both cannabis and alcohol, participants were asked whether both substances were used within the same two-hour period. Visual depictions of grams of cannabis flower and a standard drink conversion chart were available when completing relevant questions through the EMA application. Participants received between $45 and $115 CAD following the EMA period (depending on the proportion of prompted surveys completed).

Data analysis

Calculation of demand indices

Demand indices were calculated in R, using the *beezdemand* package (Kaplan et al., 2019; R Core Team, 2022). As two points of demand (i.e., consumption beyond zero cost) are required to determine elasticity, we removed participants who, on either purchase task, reported zero consumption at all prices (MPT: *n*=4; APT: *n*=1), or who only reported consumption at zero cost (MPT: *n*=5; APT: *n*=0). We then removed participants who displayed signs of non-systematic responding on either purchase task (Kaplan et al., 2019; Stein et al., 2015), including constant demand, describing less than a 0.025 log-unit reduction in consumption per log-unit range in price (MPT: *n*=17; APT: *n*=8); bounce violations, describing price-to-price increases in consumption at more than 10% of price increments (MPT: *n*=0; APT: *n*=0); or reversals from zero, describing a non-zero consumption value following zero consumption at two or more consecutive price points (MPT: *n*=29; APT: *n*=19). *N*=107 participants had valid data on both the MPT and APT and comprised the analytic sample. Participants with and without valid data on both the MPT and APT were compared on several demographic and substance-use-related characteristics (see Table S1); statistically significant group differences were observed only for AUDIT scores, with participants without valid MPT and APT data reporting greater hazardous alcohol use. Next, consistent with common practices in the purchase task literature (Kaplan et al., 2018), we examined the raw MPT and APT data (i.e., reported consumption at each price point) for extreme outliers, defined as values with *z* scores greater than 3.29. Outliers were winsorized to one unit higher than the next non-outlying value (Tabachnick & Fidell, 2007).

Estimates of intensity, O_{max}, P_{max}, and breakpoint were empirical, obtained by directly examining MPT and APT performance. In cases when multiple prices corresponded to maximum expenditure, the highest of the prices was used as P_{max}. Breakpoint was the price at which consumption was first suppressed to zero; in cases when consumption was never suppressed to zero, the highest price point was used as breakpoint. Estimates of elasticity were derived by fitting individual demand curves using the exponentiated demand curve model (Koffarnus et al., 2015): $Q = Q_0 \times 10^{k(e^{-\alpha \times (Q_0 \times C)} - 1)} + u$, where Q=consumption at each unit price; Q_0=derived intensity, or consumption at zero cost; k=a constant across individuals denoting the range of consumption in logarithmic units; C=the cost of the commodity; a=elasticity, or the rate constant determining the rate of decline in consumption with increasing price; and u=residuals. The k value was determined by subtracting the $\log_{10}$-transformed mean consumption at the maximum price from the $\log_{10}$-transformed mean consumption at the minimum price and adding 0.50 (Kaplan et al., 2019). We obtained R^2 values indicating the proportion of variance in participants' MPT and APT performance accounted for by the exponentiated demand curve models.

Multilevel models

We used multilevel multinomial logistic regression models with days (level 1) nested within participants (level 2) to examine associations of cannabis and alcohol demand (level 2 predictors) with likelihood of engaging in simultaneous use (reference category) compared to non-use, cannabis-only use, and alcohol-only use on each day (level 1 categorical outcome with four categories). Level 2 independent variables were cannabis and alcohol demand indices. Given high correlations among demand indices (Amlung et al., 2015; Aston et al., 2015), we included only one index from each task per model (e.g., cannabis O_{max} and alcohol O_{max}). As demand is a between-person variable, associations reflect between-person (level 2) relationships between demand and propensity to engage in simultaneous use (relative to non-use, alcohol-only use, and cannabis-only use), aggregated across days (i.e., the relative number of days during which simultaneous use occurred). At level 2, we controlled for age, sex, and income. As alcohol use is elevated on weekends relative to weekdays among young adults (Goldman et al., 2011; Lau-Barraco et al., 2016; Patrick et al., 2016) and participants varied in the proportion of their completed surveys that occurred on weekdays versus weekend days, we also adjusted for the percentage of each participant's observations that referred to use on weekend days (Friday–Sunday). As all independent variables of interest varied only at level 2, we did not control for any variables at level 1.

Multilevel models were also used to examine associations of cannabis and alcohol demand with cannabis and alcohol consumption on simultaneous use days. These models included only the 279 observations (days) in which both cannabis use and alcohol use were reported. In models predicting cannabis consumption, grams of cannabis flower used was modelled as a linear outcome using a gaussian distribution, and in models predicting alcohol consumption, number of standard drinks was modelled as a count outcome using a Poisson distribution. In each model, level 2 independent variables were cannabis and alcohol demand indices (one index from each task per set of models). We controlled for person-mean number of standard drinks consumed in models predicting cannabis consumption and person-mean grams of cannabis flower used in models predicting alcohol consumption. Additional level 2 covariates included in all models were person-mean percentage of days involving non-flower cannabis use, person-mean percentage of days that were weekend days (Friday–Sunday), age, sex, and income.

In all multilevel models, all independent variables and covariates were grand-mean centered. Models were fit using maximum likelihood estimation. Mplus version 8.8 (Muthén & Muthén, 2021) was used to fit multilevel multinomial logistic regression models and the glmmTMB package in R (Brooks et al., 2017; R Core Team, 2022) was used to fit all other models.

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). Anonymized data, analysis code, and research materials are available upon request to the corresponding author, subject to any applicable ethics requirements. The study's design and its analysis were not pre-registered.

Results

Descriptive statistics

Participants (*N*=107) completed a combined total of 2024 daily surveys (average 90.08% completion rate [*SD*=17.10]), of which 499 (24.65%) involved previous-day cannabis-only use, 175 (8.64%) involved previous-day alcohol-only use, 279 (13.78%) involved previous-day simultaneous use, and 1071 (52.92%) involved no previous-day cannabis or alcohol use. 240 (86.02%) simultaneous use days involved using both cannabis and alcohol within the same two-hour period. Averaging across each participant's daily surveys, participants reported an average of 4.66 (*SD*=4.91, range=0–21) cannabis-only days, 1.64 (*SD*=2.18, range=0–12) alcohol-only days, and 2.61 (*SD*=3.03, range=0–14) simultaneous use days. On average, participants reported consuming 0.61 (*SD*=0.94) and 0.37 (*SD*=0.50) grams of cannabis flower per simultaneous use day and per cannabis-only day, respectively; and 3.67 (3.85) and 2.85 (*SD*=2.17) standard drinks per simultaneous use day and per alcohol-only day, respectively. Participants reported using cannabis flower on an average of 65.91% (*SD*=42.53) of their simultaneous use days and 69.07% (*SD*=42.16) of their cannabis-only days, and using non-flower cannabis on an average of 43.05% (*SD*=44.11) of their simultaneous use days and 36.37% (*SD*=44.55) of their cannabis-only days.

The exponentiated demand curve models (Koffarnus et al., 2015) provided excellent fit to the overall data (MPT: R^2=0.99; APT: R^2=0.97) and to individual data (MPT: median R^2=0.90, interquartile range=0.82–0.95; APT: median R^2=0.90, interquartile range=0.84–0.93). Figure 1 depicts the mean consumption curves generated from MPT and APT performance. Correlations among all cannabis and alcohol demand indices are shown in Supplementary Table S2.

Associations of cannabis and alcohol demand with propensity for simultaneous use

Results of multilevel multinomial logistic regression models examining associations of cannabis demand and alcohol demand with propensity for simultaneous use compared to non-use, cannabis-only use, and alcohol-only use are reported in Table 2. Controlling for covariates, higher cannabis $O_{\max}$, higher cannabis $P_{\max}$, higher cannabis intensity, and lower cannabis elasticity (indicating greater demand) were associated with greater propensity for simultaneous use relative to non-use. By contrast, associations of each alcohol demand index and of cannabis breakpoint with propensity for simultaneous use relative to non-use were not statistically significant. In addition, lower alcohol elasticity was significantly associated with greater propensity for simultaneous use relative to cannabis-only use, whereas we did not observe evidence to support associations of each cannabis demand index and of alcohol O_{max}, alcohol P_{max}, alcohol breakpoint, and alcohol intensity with propensity for simultaneous use relative to cannabis-only use. Further, higher cannabis breakpoint, higher cannabis intensity, and lower cannabis elasticity were significantly associated with greater propensity for simultaneous use relative to alcohol-only use. However, associations of each alcohol demand index and of cannabis O_{max} and cannabis P_{max} with propensity for simultaneous use relative to alcohol-only use were not statistically significant.

Associations of cannabis and alcohol demand with consumption on simultaneous use days

Results of multilevel models examining associations of cannabis demand and alcohol demand with cannabis consumption and alcohol consumption on simultaneous use days are reported in Tables 3 and 4, respectively. After adjusting for covariates, higher cannabis O_{max}, lower cannabis elasticity, and higher alcohol elasticity were significantly associated with using a larger amount of cannabis flower on simultaneous use days; associations of alcohol O_{max}, alcohol P_{max}, alcohol breakpoint, alcohol intensity, cannabis P_{max}, cannabis breakpoint, and cannabis intensity with cannabis flower consumption on simultaneous use days were not statistically significant. Higher alcohol O_{max} and lower alcohol elasticity were significantly associated with consuming a larger number of standard drinks on simultaneous use days, whereas each cannabis demand index and alcohol P_{max}, alcohol breakpoint, and alcohol intensity were not significantly associated with alcohol consumption on simultaneous use days.

Discussion

Although behavioural economic demand for cannabis and alcohol are robustly associated with cannabis use and alcohol use, respectively, few studies have examined their contributions to simultaneous use. We examined individual differences in cannabis and alcohol demand as predictors of propensity for simultaneous use and amount of each substance consumed on simultaneous use days. As hypothesized, higher alcohol demand, and specifically, lower sensitivity to escalating alcohol costs (elasticity), was uniquely associated with a greater propensity for simultaneous use relative to cannabis-only use. Correspondingly, higher cannabis demand, in terms of amount of hypothetical cannabis use at zero cost (intensity), the price at which cannabis consumption was suppressed to zero (breakpoint), and insensitivity to escalating cannabis costs (elasticity), was uniquely associated with a greater propensity for simultaneous use relative to alcohol-only use. Extending past work showing that cannabis and alcohol demand are associated with frequency of cannabis and alcohol use, respectively, when examined separately (Aston & Cassidy, 2019; González-Roz et al., 2022; Martínez-Loredo et al., 2021), the current findings demonstrate that it is elevated demand for cannabis, specifically, that predicts a greater tendency to combine cannabis with alcohol rather than to use alcohol alone (and vice versa for alcohol demand). These findings support the notion that cannabis and alcohol demand each contribute uniquely and in a substance-specific manner to simultaneous use behaviour. Prior research comparing demand between people reporting polysubstance use (e.g., alcohol and nicotine, alcohol and cannabis; Amlung et al., 2017; Morris et al., 2018; Naudé et al., 2021) versus single-substance use has been equivocal as to whether elevated demand among those reporting polysubstance use reflects a heightened relative valuation of the substance for which demand was assessed, or rather points to a generic hypersensitivity to reward (Amlung et al., 2017). Our results, in demonstrating distinct patterns of demand underlying a propensity for simultaneous use relative to alcohol-only use and cannabis-only use, add support for the substance-specificity of indices of cannabis and alcohol demand from hypothetical purchase tasks, aligning with previous findings (Strickland et al., 2017).

An important finding was that higher cannabis demand across all indices except breakpoint predicted a greater propensity for simultaneous use relative to non-use. However, in contrast to our hypotheses, we did not observe evidence to support associations of alcohol demand indices with propensity for simultaneous use relative to non-use. In other words, demand for cannabis and alcohol did not appear to have an additive effect in predicting simultaneous use compared to no use at all; rather, it was heightened demand for cannabis, specifically, that predicted a greater overall tendency to use cannabis and alcohol simultaneously versus abstain from using either substance. This may reflect the tendency for simultaneous use events to involve heavier cannabis use relative to cannabis-only days (Jackson et al., 2021), making cannabis demand most relevant for predicting simultaneous use. Indeed, in our study, simultaneous use days involved an average of 0.61 (*SD*=0.94) grams of cannabis flower compared to an average of 0.39 (*SD*=0.54) grams of cannabis flower on cannabis-only days. Further, as participants in our study reported relatively light alcohol use, including on simultaneous use days (average 3.67 standard drinks [*SD*=3.05]), it is possible that alcohol demand was less relevant than cannabis demand in differentiating simultaneous use days from non-use days in our sample. However, this interpretation is speculative and should be clarified in future research.

This study also examined individual differences in cannabis and alcohol demand as predictors of average cannabis and alcohol consumption on simultaneous use days. Controlling for use of and demand for the other substance, we found that higher cannabis demand (in terms of O_{max} and elasticity) was associated with using more grams of cannabis flower on average on simultaneous use days, and higher alcohol demand (in terms of O_{max} and elasticity) was associated with consuming more standard drinks on average on simultaneous use days. These results broadly concord with previous research supporting associations of higher cannabis and alcohol demand with greater cannabis and alcohol consumption, respectively (Aston & Cassidy, 2019; González-Roz et al., 2022; Martínez-Loredo et al., 2021; Zvorsky et al., 2019). Associations of O_{max} and elasticity, specifically, with consumption are unsurprising given evidence that these demand indices are among those most robustly associated with substance-use-related outcomes (Zvorsky et al., 2019), although results depart from the robust intensity-consumption associations generally observed in the literature (Zvorsky et al., 2019), tentatively suggesting that intensity may be less relevant in predicting consumption in the context of simultaneous use relative to single-substance use. In addition, cannabis demand-consumption associations align with one study finding that higher cannabis demand (in terms of intensity) was associated with consuming more grams of cannabis flower per week, holding alcohol demand constant (Strickland et al., 2017). The tendency for elevated cannabis demand to predict cannabis consumption above and beyond contributions of alcohol demand and vice versa further evinces that behavioural economic relations of cannabis and alcohol demand with cannabis and alcohol use outcomes are likely substance-specific, rather than indicative of a general heightened sensitivity to reward.

Interestingly, whereas we did not observe evidence for associations between cannabis demand and average alcohol consumption on simultaneous use days, one index of alcohol demand (lower elasticity) was significantly associated with consuming more cannabis on simultaneous use days. This finding is similar to results of a study that found a unique association of lower alcohol demand (in terms of intensity) with consuming more grams of cannabis flower on average per week (Strickland et al., 2017). As this association was observed in the present study while holding cannabis elasticity and average alcohol consumption on simultaneous use days constant, it does not appear to be driven by differences in cannabis demand or alcohol consumption among those with lower scores on alcohol elasticity. It is possible that more elastic alcohol demand is a proxy for other characteristics that covary with using more cannabis flower. However, given that this negative association between alcohol demand and cannabis consumption was limited to a single demand index, further research is needed to identify mechanisms of this unexpected finding.

In elucidating the contributions of cannabis and alcohol demand to simultaneous use behaviours, results of this study suggest that interventions targeting cannabis and alcohol demand may have utility for preventing simultaneous use and reducing associated harms, which should be explored in future research. Importantly, contemporary behavioural economic models of substance use, such as the contextualized reinforcer pathology model (Acuff, MacKillop, et al., 2023), posit that although elevated demand contributes to greater substance use, elevations in both demand and substance use are influenced by a broader choice context (Acuff, MacKillop, et al., 2023)—namely, by the availability of the substance(s) relative to alternative, substance-free reinforcers, among other contextual factors (Acuff et al., 2020). Relatedly, recent data suggest that stable individual differences, such as relative deficits in executive functions (e.g., working memory, inhibitory control), may subserve elevations in trait cannabis and alcohol demand (Abram et al., 2021; Coelho et al., in press). Thus, behavioral economic intervention efforts for simultaneous use could aim to reduce cannabis and alcohol demand both directly (i.e., by increasing price or decreasing availability) and by way of manipulating of their causal antecedents. For example, increasing young adults' access to substance-free reinforcement may be critical in attenuating cannabis and alcohol demand, and in turn, reducing simultaneous use. Future research is needed to explore the potential utility of extending existing behavioural economic interventions for alcohol and cannabis use, such as substance-free activity sessions (e.g., Coughlin et al., 2023; Murphy et al., 2012, 2019; Yurasek et al., 2015), to simultaneous use.

Limitations and Future Directions

This study had several strengths, including daily assessment of cannabis use, alcohol use, and simultaneous use frequencies, as well as of cannabis and alcohol consumption during simultaneous use occasions. Further, our prospective design permitted an examination of temporal relations of individual differences in demand indices with individual differences in simultaneous use behaviours. Still, there were several limitations. First, a subset of participants (n=43, 28.48% of the larger sample) provided purchase task data that were excluded from analyses due to exhibiting non-systematic response patterns, reducing our analytic sample size. Some of these participants' data were excluded due to constant demand across all price points, or due to reporting consumption only when cannabis or alcohol were offered at zero cost. As constant demand and consumption only at zero cost can reflect non-systematic responding (e.g., repeating the same consumption value across all price points to rush through the measure), we removed data from participants exhibiting these response patterns, as is common when analyzing purchase task data (Kaplan et al., 2018; Stein et al., 2015). However, it is possible that in some cases, these response patterns were valid; if valid, constant consumption across all price points would reflect extremely inelastic demand and consumption only at zero cost would reflect highly elastic demand. Although few participants in our study exhibited these specific response patterns in the absence of other indicators of non-systematic responding (MPT: *n*=9; APT: *n*=1), it is possible that their exclusion may have restricted the range of demand in our sample and limited the generalizability of our results. As previous studies have been mixed in their approach to handling purchase task data that exhibit these response patterns, additional psychometric work on best practices in handling non-systematic purchase task data is an important future research direction.

Another limitation related to our purchase tasks was that the MPT and APT differed in consumption units (grams of cannabis flower versus standard drinks) and time frames (one week versus five hours), precluding direct comparisons between MPT and APT indices. As well, the MPT only assessed demand for cannabis flower, which although was the predominant form of cannabis used in our sample, excluded other cannabis products such as cannabis concentrates and edibles. In addition, although we used validated APT instructions and price points (Kaplan et al., 2018; Murphy & MacKillop, 2006), several participants (*n*=54) did not report zero consumption at any price point on the APT, potentially causing a ceiling effect with respect to alcohol breakpoint. Further, as all indices of cannabis and alcohol demand in our study were drawn from single-substance purchase tasks, future research should consider the roles of cannabis and alcohol demand indices drawn from cross-commodity purchase tasks (e.g., see Dolan et al., 2022) in simultaneous use behaviors.

An additional limitation is that our study applied a broad definition of simultaneous use (i.e., same-day co-use), which did not necessarily align with the more standard definition of using cannabis and alcohol at the same time or with overlapping effects. Notably, 86% of simultaneous use days involved cannabis and alcohol use within the same two-hour period, increasing confidence that same-day co-use largely reflected simultaneous use. Still, we opted not to limit our definition of simultaneous use to days involving cannabis and alcohol use within the same two-hour period given that the effects of cannabis may have persisted beyond two hours if administered orally. Further, as cannabis and alcohol demand were only measured at one time point, associations of demand indices with simultaneous use behaviours were modelled at the between-person level, but not at the within-person level. Given emerging evidence of within-person associations of alcohol demand (assessed daily) with same-day alcohol consumption (Aston & Merrill, 2023), future research assessing cannabis and alcohol demand and simultaneous use behaviours daily is needed to examine within-person associations of demand with simultaneous use. Due to our modest sample size of $N = 107$, we also did not examine potential moderators of the associations observed. Future studies with larger samples could consider testing moderators of associations of demand indices with simultaneous use behaviours, including potential interactive effects of cannabis and alcohol demand on simultaneous use behaviours.

Several factors may also limit the generalizability of our findings. Notably, all participants in the current study were young adults already reporting simultaneous use. Excluding participants who reported only cannabis or alcohol use may have attenuated the associations we observed of demand with simultaneous use behaviours. Further, findings may not generalize to young adults who are treatment-seeking; who use cannabis and alcohol less frequently; who use substances other than alcohol, cannabis, or nicotine; or who reside in jurisdictions where cannabis is not legal.

Conclusions

This study extends prior research on simultaneous use by examining prospective associations of individual differences in cannabis and alcohol demand with simultaneous use behaviours. Findings suggest that cannabis and alcohol demand may contribute to simultaneous use behaviours in a pattern that is generally substance-specific, although cannabis demand may more strongly drive the tendency to engage in simultaneous use (versus to not use either substance) relative to alcohol demand. As findings support the importance of cannabis and alcohol demand in understanding simultaneous use behaviours, future research should examine whether harm reduction interventions for simultaneous use among young adults may benefit from content targeting demand for each substance.

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Table 1. Sample characteristics (N = 107)

	n (%)
Sex[a]	
Male	41 (38.32)
Female	65 (60.74)
Gender[b]	
Man	44 (41.12)
Woman	61 (57.01)
Transgender	2 (1.87)
Non-binary	3 (2.80)
Race/ethnicity[b]	
White/Caucasian	67 (62.62)
Black/African Descent/African	11 (10.28)
Asian	17 (15.89)
Pacific Islander	2 (1.87)
Indigenous/Native North American	0 (0.00)
East Indian	12 (11.21)
Middle Eastern	4 (3.74)
Hispanic/Latinx	3 (2.80)
Prefer to specify	2 (1.87)
Prefer not to respond	1 (0.93)
Household income[c]	
$0–$19,999	22 (20.56)
$20,000–$49,999	34 (31.78)
$50,000–$99,999	24 (22.43)
$100,000–$159,999	10 (9.35)
$160,000+	15 (14.02)
Highest level of education	
Less than high school, GED, or high school diploma	33 (30.84)
Some college, technical certification, or associates degree	29 (27.11)
Bachelors degree	43 (40.19)
Masters or doctoral degree	2 (1.87)
DFAQ-CU current cannabis use frequency[d]	
2–3 times a month	7 (6.54)
Once a week	16 (14.95)
Twice a week	24 (22.43)
3–4 times a week	22 (20.56)
5–6 times a week	12 (11.21)
Once a day	20 (18.69)
More than once a day	6 (5.61)
NIAAA past-12-month alcohol use frequency	
Zero times	0 (0.00)
1 to 11 times in the past year	5 (4.67)
Once a month	2 (1.87)
2 to 3 times a month	20 (18.69)
Once a week	28 (26.17)
Twice a week	31 (28.97)
3 to 4 times a week	17 (15.89)
5 or more times a week	4 (3.74)
NIAAA past-12-month standard drinks consumed on a typical drinking day	
1 drink	14 (13.08)
2 drinks	32 (29.91)
3 to 4 drinks	41 (38.32)

5 to 6 drinks	13 (12.15)
7 to 8 drinks	6 (5.61)
9 to 11 drinks	1 (0.93)
12 to 15 drinks	0 (0.00)
16 to 18 drinks	0 (0.00)
19 to 24 drinks	0 (0.00)
25 or more drinks	0 (0.00)
NIAAA past-12-month largest number of drinks consumed in a 24-hour period	
1 to 4 drinks	15 (14.02)
5 to 7 drinks	28 (26.17)
8 to 11 drinks	36 (33.64)
12 to 17 drinks	22 (20.56)
18 to 23 drinks	4 (3.74)
24 to 35 drinks	2 (1.87)
36 drinks or more	0 (0.00)
NIAAA past-12-month frequency of 4 or more standard drinks (female) or 5 or more standard drinks (male) within a two-hour period	
Zero times	1 (0.93)
1 or 2 times in the past year	30 (28.04)
3 to 11 times in the past year	27 (25.23)
Once a month	12 (11.21)
2 to 3 times a month	22 (20.56)
Once a week	11 (10.28)
Twice a week	4 (3.74)
3 to 4 times a week	0 (0.00)
5 to 6 times a week	0 (0.00)
Everyday	0 (0.00)
	M (*SD*)
Age	22.06 (2.14)
CUDIT-R total score	9.51 (5.52)
AUDIT total score	7.15 (4.07)
DFAQ-CU grams of cannabis flower used in a typical session	0.32 (0.27)
DFAQ-CU grams of cannabis flower used in a typical day	0.42 (0.45)
DFAQ-CU grams of cannabis flower used in a typical week	1.89 (2.65)
MPT O_{max}	38.10 (33.37)
MPT P_{max}	15.03 (11.83)
MPT breakpoint	25.51 (14.49)
MPT intensity	7.44 (8.19)
MPT elasticity	0.01 (0.02)
APT O_{max}	32.06 (15.14)
APT P_{max}	8.81 (5.09)
APT breakpoint	17.58 (4.22)
APT intensity	8.56 (4.08)
APT elasticity	0.01 (0.01)

Note. CUDIT-R = Cannabis Use Disorder Identification Test; AUDIT = Alcohol Use Disorder Identification Test; DFAQ-CU = Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory; NIAAA = National Institute on Alcohol Abuse and Alcoholism Alcohol Screening Questions; MPT = Marijuana Purchase Task; APT = Alcohol Purchase Task. [a]One participant was missing data; [b]Participants could select more than one option; [c]Two participants were missing data; [d]No participants reported using cannabis less than 2–3 times a month, and thus lower frequency categories are not included in the table.

Table 2. Associations of cannabis demand and alcohol demand with propensity for simultaneous use compared to non-use, cannabis-only use, and alcohol-only use

	Non-use vs. simultaneous use [ref.]				**Alcohol-only vs. simultaneous use [ref.]**				**Cannabis-only vs. simultaneous use [ref.]**			
	OR	Estimate	*SE*	*p*	OR	Estimate	*SE*	*p*	OR	Estimate	*SE*	*p*
O_{max}												
MPT O_{max}	**0.99**	**-0.01**	**0.01**	**0.038**	0.98	-0.02	0.01	0.070	1.00	<0.01	<0.01	0.556
APT O_{max}	0.99	-0.01	0.01	0.499	1.00	<0.01	0.01	0.663	1.00	<0.01	0.01	0.694
Age	0.96	-0.04	0.07	0.546	1.07	0.06	0.07	0.357	0.95	-0.05	0.07	0.471
Sex	1.58	0.46	0.31	0.147	1.57	0.45	0.32	0.165	**1.90**	**0.64**	**0.29**	**0.028**
Income	1.03	0.03	0.04	0.424	0.99	-0.01	0.05	0.862	1.03	0.03	0.03	0.412
Percentage weekend days	1.03	0.03	0.05	0.566	1.03	0.03	0.04	0.456	1.02	0.02	0.04	0.605
P_{max}												
MPT P_{max}	**0.97**	**-0.03**	**0.01**	**0.014**	0.99	-0.02	0.01	0.057	1.00	<0.01	0.01	0.789
APT P_{max}	1.03	0.03	0.03	0.411	1.00	<0.01	0.03	0.949	0.99	-0.01	0.03	0.655
Age	1.01	0.01	0.07	0.856	1.12	0.11	0.07	0.131	0.95	-0.05	0.06	0.410
Sex	1.61	0.48	0.30	0.110	1.57	0.45	0.33	0.168	**1.90**	**0.64**	**0.29**	**0.027**
Income	1.03	0.03	0.04	0.401	1.00	<0.01	0.05	0.972	1.02	0.02	0.03	0.499
Percentage weekend days	1.02	0.02	0.05	0.625	1.03	0.03	0.04	0.503	1.02	0.02	0.04	0.629
Breakpoint												
MPT breakpoint	0.99	-0.02	0.01	0.099	**0.98**	**-0.02**	**0.01**	**0.027**	1.01	0.01	0.01	0.396
APT breakpoint	1.01	0.01	0.04	0.873	0.98	-0.02	0.04	0.660	1.02	0.02	0.04	0.695
Age	0.99	-0.01	0.07	0.875	1.10	0.10	0.07	0.179	0.95	-0.05	0.06	0.447
Sex	1.59	0.47	0.31	0.132	1.56	0.44	0.34	0.189	**1.92**	**0.65**	**0.30**	**0.030**
Income	1.03	0.03	0.04	0.470	0.99	-0.01	0.05	0.890	1.03	0.03	0.03	0.396
Percentage weekend days	1.03	0.03	0.05	0.583	1.03	0.03	0.04	0.456	1.02	0.02	0.04	0.619
Intensity												
MPT intensity	**0.95**	**-0.05**	**0.02**	**0.003**	**0.93**	**-0.07**	**0.03**	**0.010**	1.01	0.01	0.02	0.609
APT intensity	0.96	-0.04	0.03	0.285	0.98	-0.02	0.04	0.613	0.96	-0.04	0.03	0.225
Age	0.96	-0.05	0.07	0.528	1.07	0.07	0.07	0.369	0.94	-0.06	0.06	0.314
Sex	1.75	0.56	0.30	0.060	1.73	0.55	0.34	0.104	**1.86**	**0.62**	**0.29**	**0.030**
Income	1.04	0.04	0.04	0.327	1.00	<0.01	0.05	0.968	1.03	0.03	0.03	0.411
Percentage weekend days	1.03	0.03	0.05	0.592	1.03	0.03	0.04	0.457	1.03	0.03	0.04	0.499
Elasticity												
MPT elasticity	**$7.77*e^{19}$**	**45.80**	**21.53**	**0.033**	**$6.06*e^{20}$**	**47.85**	**20.91**	**0.022**	<0.01	-36.05	25.01	0.149
APT elasticity	<0.01	-8.28	16.22	0.610	<0.01	-8.20	15.80	0.604	**$3.47*e^{15}$**	**35.78**	**16.85**	**0.034**
Age	0.96	-0.04	0.07	0.577	1.08	0.07	0.07	0.291	0.94	-0.06	0.06	0.358
Sex	1.51	0.41	0.32	0.188	1.44	0.37	0.32	0.259	**2.07**	**0.73**	**0.30**	**0.015**
Income	1.03	0.03	0.04	0.425	1.00	<0.01	0.04	0.952	1.03	0.03	0.03	0.402
Percentage weekend days	1.02	0.02	0.05	0.663	1.02	0.02	0.04	0.567	1.03	0.03	0.04	0.501

Note. OR = odds ratio, SE = standard error, ref. = reference category, MPT = Marijuana Purchase Task, APT = Alcohol Purchase Task. All independent variables were grand-mean centered. Three participants were excluded from models due to missing demographic data. Bolding indicates statistical significance at *a* = 0.05.

Table 3. Associations of cannabis demand and alcohol demand with cannabis flower consumption on simultaneous use days

	Estimate	*SE*	*p*
O_{max}			
MPT O_{max}	**0.007**	**0.002**	**0.002**
APT O_{max}	0.000	0.005	0.996
Person-mean standard drinks	0.048	0.032	0.135
Percentage of days involving non-flower cannabis use	**-0.536**	**0.165**	**0.001**
Percentage of days that were weekend days	**-0.068**	**0.027**	**0.014**
Age	**0.074**	**0.033**	**0.025**
Sex	-0.115	0.143	0.420
Income	-0.006	0.018	0.718
P_{max}			
MPT P_{max}	0.002	0.007	0.772
APT P_{max}	0.004	0.014	0.787
Person-mean standard drinks	0.054	0.032	0.090
Percentage of days involving non-flower cannabis use	**-0.557**	**0.173**	**0.001**
Percentage of days that were weekend days	-0.054	0.029	0.059
Age	0.067	0.036	0.063
Sex	-0.099	0.151	0.515
Income	-0.011	0.019	0.577
Breakpoint			
MPT breakpoint	0.008	0.005	0.097
APT breakpoint	0.016	0.017	0.357
Person-mean standard drinks	0.050	0.031	0.113
Percentage of days involving non-flower cannabis use	**-0.567**	**0.165**	**0.001**
Percentage of days that were weekend days	**-0.058**	**0.028**	**0.037**
Age	0.065	0.034	0.054
Sex	-0.085	0.149	0.567
Income	-0.007	0.019	0.724
Intensity			
MPT intensity	0.012	0.009	0.190
APT intensity	0.007	0.019	0.702
Person-mean standard drinks	0.057	0.032	0.072
Percentage of days involving non-flower cannabis use	**-0.498**	**0.169**	**0.003**
Percentage of days that were weekend days	**-0.058**	**0.029**	**0.044**
Age	**0.070**	**0.034**	**0.041**
Sex	-0.146	0.151	0.335
Income	-0.011	0.019	0.557
Elasticity			
MPT elasticity	**-30.810**	**11.130**	**0.006**
APT elasticity	**39.100**	**18.530**	**0.035**
Person-mean standard drinks	**0.064**	**0.030**	**0.030**
Percentage of days involving non-flower cannabis use	**-0.475**	**0.162**	**0.003**
Percentage of days that were weekend days	-0.047	0.027	0.086
Age	**0.072**	**0.032**	**0.026**
Sex	-0.036	0.139	0.798
Income	-0.001	0.017	0.969

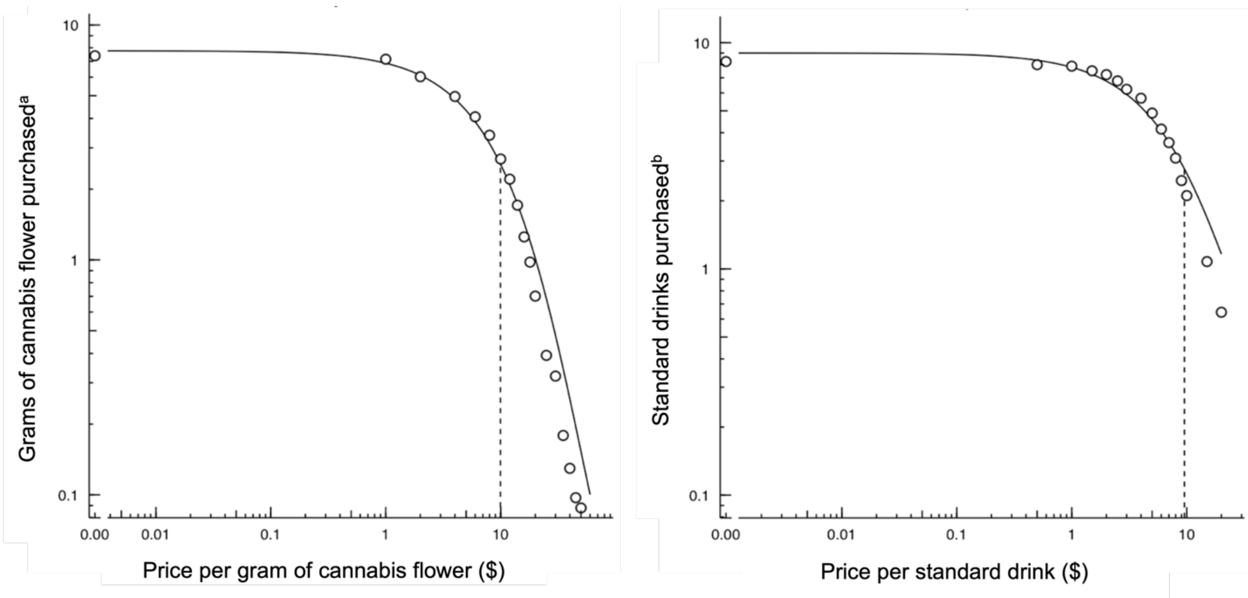
Note. SE = standard error, MPT = Marijuana Purchase Task, APT = Alcohol Purchase Task. All independent variables were grand-mean centered. 36 participants were excluded from models due to reporting no simultaneous use days during the ecological momentary assessment period; an additional participant was excluded from models due to missing demographic data. Bolding indicates statistical significance at *a* = 0.05.

Table 4. Associations of cannabis demand and alcohol demand with alcohol consumption on simultaneous use days

	RR	Estimate	*SE*	*p*
O_{max}				
MPT O_{max}	1.001	0.001	0.002	0.617
APT O_{max}	**1.011**	**0.011**	**0.004**	**0.005**
Person-mean grams of cannabis flower	1.229	0.206	0.117	0.079
Percentage of days involving non-flower cannabis use	0.766	-0.267	0.166	0.109
Percentage of days that were weekend days	0.990	-0.011	0.027	0.698
Age	**0.922**	**-0.081**	**0.032**	**0.011**
Sex	**0.755**	**-0.281**	**0.131**	**0.032**
Income	0.992	-0.008	0.017	0.630
P_{max}				
MPT P_{max}	1.003	0.003	0.007	0.669
APT P_{max}	1.008	0.008	0.014	0.546
Person-mean grams of cannabis flower	**1.265**	**0.235**	**0.116**	**0.042**
Percentage of days involving non-flower cannabis use	0.823	-0.195	0.174	0.261
Percentage of days that were weekend days	0.997	-0.003	0.028	0.917
Age	**0.914**	**-0.090**	**0.034**	**0.009**
Sex	**0.745**	**-0.295**	**0.141**	**0.037**
Income	0.998	-0.002	0.018	0.892
Breakpoint				
MPT breakpoint	0.999	-0.001	0.005	0.806
APT breakpoint	1.021	0.021	0.017	0.231
Person-mean grams of cannabis flower	1.258	0.229	0.121	0.059
Percentage of days involving non-flower cannabis use	0.830	-0.187	0.172	0.277
Percentage of days that were weekend days	0.997	-0.003	0.028	0.901
Age	**0.920**	**-0.083**	**0.034**	**0.013**
Sex	**0.714**	**-0.337**	**0.141**	**0.017**
Income	0.993	-0.007	0.018	0.699
Intensity				
MPT intensity	0.998	-0.002	0.009	0.782
APT intensity	1.017	0.017	0.018	0.340
Person-mean grams of cannabis flower	**1.275**	**0.243**	**0.117**	**0.038**
Percentage of days involving non-flower cannabis use	0.863	-0.147	0.170	0.387
Percentage of days that were weekend days	0.993	-0.007	0.028	0.805
Age	**0.919**	**-0.085**	**0.033**	**0.011**
Sex	**0.725**	**-0.321**	**0.141**	**0.023**
Income	0.996	-0.004	0.018	0.815
Elasticity				
MPT elasticity	0.330	-1.108	12.166	0.927
APT elasticity	**<0.001**	**-45.780**	**19.983**	**0.022**
Person-mean grams of cannabis flower	**1.355**	**0.304**	**0.122**	**0.013**
Percentage of days involving non-flower cannabis use	0.791	-0.235	0.171	0.170
Percentage of days that were weekend days	0.982	-0.018	0.028	0.526
Age	**0.927**	**-0.075**	**0.034**	**0.025**
Sex	**0.716**	**-0.335**	**0.136**	**0.014**
Income	0.993	-0.007	0.017	0.676

Note. RR = rate ratio, SE = standard error, MPT = Marijuana Purchase Task, APT = Alcohol Purchase Task. All independent variables were grand-mean centered. 36 participants were excluded from models due to reporting no simultaneous use days during the ecological momentary assessment period; an additional participant was excluded from models due to missing demographic data. Bolding indicates statistical significance at $a = 0.05$.

Figure 1. Cannabis and alcohol demand curves



Note. Curve for consumption of cannabis grams (left) and standard drinks (right). The *x*-axis provides log-transformed price in dollars and the *y*-axis provides mean cannabis grams purchased (left) and mean standard drinks purchased (right).
[a]Purchased for consumption during a typical week.
[b]Purchased for consumption during a five-hour party.

Supplementary Table S1. Characteristics of participants with and without valid purchase task data

	Participants with valid purchase task data (N = 107)	Participants without valid purchase task data (N = 43)		
	n (%)	n (%)	χ^2 (df)	p
Sex			0.61 (1)	0.433
Male	41 (38.32)	13 (30.23)		
Female	65 (60.75)	30 (69.77)		
Household income			0.38 (4)	0.984
$0–$19,999	22 (20.56)	10 (23.26)		
$20,000–$49,999	34 (31.78)	13 (30.23)		
$50,000–$99,999	24 (22.43)	11 (25.58)		
$100,000–$159,999	10 (9.35)	4 (9.30)		
$160,000+	15 (14.02)	5 (11.63)		
Highest level of education			3.43 (3)	0.330
Less than high school, GED, or high school diploma	33 (30.84)	19 (44.19)		
Some college, technical certification, or associates degree	29 (27.10)	12 (27.91)		
Bachelors degree	43 (40.19)	11 (25.58)		
Masters or doctoral degree	2 (1.87)	1 (2.33)		
	M (SD)	M (SD)	t (df)	p
Age	22.07 (2.14)	22.05 (2.05)	-0.05 (80.77)	0.960
CUDIT-R total score	9.51 (5.52)	11.30 (4.88)	1.95 (87.11)	0.054
AUDIT total score	**7.15 (4.07)**	**10.35 (5.22)**	**3.60 (63.50)**	**<0.001**
Proportion of daily surveys involving co-use	0.28 (0.27)	0.31 (0.28)	0.68 (71.15)	0.501
Proportion of daily surveys involving cannabis-only use	0.47 (0.35)	0.47 (0.34)	-0.01 (75.00)	0.988
Proportion of daily surveys involving alcohol-only use	0.25 (0.31)	0.22 (0.30)	-0.59 (73.52)	0.555
Average number of standard drinks consumed across days involving co-use	1.10 (1.75)	1.17 (1.18)	0.27 (105.92)	0.787
Average number of grams of cannabis flower consumed across days involving co-use	0.15 (0.35)	0.20 (0.47)	0.57 (56.85)	0.568

Note. CUDIT-R = Cannabis Use Disorder Identification Test – Revised; AUDIT = Alcohol Use Disorder Identification Test; M = mean; SD = standard deviation; df = degrees of freedom. Bolding indicates statistical significance at a = 0.05.

Supplementary Table S2. Zero-order correlations among cannabis and alcohol demand indices

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. MPT O_{max}	–									
2. MPT P_{max}	0.26**	–								
3. MPT breakpoint	0.54***	0.69***	–							
4. MPT intensity	0.80***	-0.05	0.28**	–						
5. MPT elasticity	-0.97***	-0.21*	-0.54***	-0.82***	–					
6. APT O_{max}	0.03	0.06	0.05	0.02	-0.07	–				
7. APT P_{max}	-0.01	0.19*	0.25*	-0.09	-0.01	0.20*	–			
8. APT breakpoint	0.07	0.05	0.05	0.05	-0.08	0.36***	0.47***	–		
9. APT intensity	0.09	-0.01	-0.12	0.22*	-0.09	0.58***	-0.28**	0.02	–	
10. APT elasticity	-0.04	-0.11	-0.07	-0.01	0.07	-0.94***	-0.27**	-0.45***	-0.46***	–

Note. MPT = Marijuana Purchase Task; APT = Alcohol Purchase Task. Spearman rank-order correlation coefficients were used due to non-normal distributions of several demand indices.

* $p < 0.05$, ** $p < 0.01$, ** $p < 0.001$