

Behavioral economics of cigarette and cannabis co-use: Validating cigarette and cannabis single and cross-commodity purchase tasks

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Abstract

Rationale. Smoking both cigarettes and cannabis increases disease risk and can reduce the odds of cigarette smoking cessation, undermining efforts to reduce smoking-related death and disease. Evidence suggests that cigarette and cannabis smoking are mutually reinforcing, however, the mechanisms that support this relation are unclear. Behavioral economics can elucidate relations between cigarette and cannabis co-use using hypothetical purchase tasks (HPTs), but these tasks must be validated to ensure accuracy and avoid potential biases.

Objectives. To assess the validity and measurement equivalence of cannabis Single and Cross-Commodity HPTs among people who co-use cigarettes and cannabis.

Methods. Participants (Co-Use [n=124]; smoke cigarettes only comparison group, CigOnly [n=22]) completed Single-Commodity (SC) Cigarette and Cannabis HPTs followed by Cigarette manipulated and Cannabis manipulated Cross-Commodity (CC) HPTs. Data was examined for systematicity followed by convergent and discriminant validity and measurement equivalence using correlations between demand intensity and measures of nicotine and cannabis dependence.

Results. All HPTs demonstrated reasonable systematicity, convergent and discriminant validity, and measurement equivalence with a few caveats. Co-Use participants were less likely to complete HPTs and submit systematic responses than CigOnly participants. The SC Cannabis HPT failed to show convergent measurement equivalence between the overall sample and Co-Use participants, and the CC Cannabis manipulated HPT failed to show convergent validity with measures of cannabis dependence.

Conclusions. Co-use was associated with HPT non-completion and non-systematic responding. Cannabis dependence measures employed were only useful for assessing convergent validity in the overall sample with the variability provided by CigOnly participants.

INTRODUCTION

Cigarette smoking continues to cause an extraordinary amount of death and disease in the United States (US) (National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health 2014; Substance Abuse and Mental Health Services Administration 2021). A substantial and growing proportion of people who smoke cigarettes in the US also smoke cannabis, and smoking remains, by far, the most frequent route of cannabis administration (Quader et al. 2025). Smoking both cigarettes and cannabis increases risk for lung cancer and other respiratory diseases and reduces the odds of achieving cigarette smoking cessation,(Weinberger et al. 2020, 2021; Dave DM, Liang Y, Pesko MF, Phillips S, Sabia JJ 2022; McClure et al. 2025; Gallagher et al. 2026) undermining efforts to reduce smoking-related death and disease.

The prevalence of cigarette and cannabis co-use has been steadily increasing in concert with increases in cannabis use (Weinberger et al. 2022; Rubenstein et al. 2024). In 2021, the prevalence of regular daily cannabis use among young adults reached 11%, the highest levels ever recorded (NIDA 2022). Among older adults, past-year cannabis use increased 75% from 2015 to 2018 (Han and Palamar 2020). At present, about 40% of people who smoke cigarettes have used cannabis in the past 30 days,(Xue et al. 2026) and 70–90% of people who use cannabis regularly smoke cigarettes (Agrawal et al. 2012; Goodwin et al. 2018).

Evidence suggests that cigarette and cannabis smoking are mutually reinforcing,(Rabin and George 2015; Subramaniam et al. 2016) however, the mechanisms that support this relation are unclear (Rabin and George 2015; Subramaniam et al. 2016; Peters et al. 2021). Co-use is linked with greater nicotine dependence,(Rubinstein et al.

2014) the propensity for relapse to cigarette smoking,(Fiore et al. 2008; Weinberger et al. 2020, 2021) and a diminished response to evidence-based smoking cessation treatments (Tullis et al. 2003; Scherma et al. 2008, 2016; Rabin and George 2015; Subramaniam et al. 2016; McClure et al. 2019, 2020; Britton et al. 2020; Weinberger et al. 2021; Goodwin et al. 2022). To date, there has been little success improving cigarette smoking cessation among people who smoke cannabis (Nguyen et al. 2024). Increased understanding of the mechanisms that facilitate and maintain cigarette smoking among people who smoke cannabis explicate these relations and perhaps identify new therapeutic targets for cigarette smoking cessation for this population.

Behavioral economic frameworks yield robust information about the reinforcing value of substances in relation to other substances (Weinsztok et al. 2023). Hypothetical purchase tasks (HPTs) are used to measure the reinforcing value, or demand, for substances (Roma et al. 2017). Demand for substances is linked with the quantity and frequency of substance use and the severity of substance use disorders (Nighbor et al. 2019; Strickland et al. 2020; Ferguson et al. 2021). Single commodity (SC) HPTs assess demand by asking people to estimate how much of a substance they would purchase at escalating prices. Cross-commodity (CC) HPTs assess the relatedness of two substances by assessing how demand for one substance changes when other substances are available at escalating prices (Bickel et al. 1995; Hursh et al. 2013; Weinsztok et al. 2023). Like all scientific measures, however, HPTs must be interpreted in the context of their psychometric properties including validity (i.e., the degree to which the HPT measures what it is intended to measure)(Swan et al. 2023) measurement equivalence within specific populations (Stein et al. 2015; Putnick and Bornstein 2016; Frongillo et al. 2019). Consideration of the psychometric qualities of HPTs is needed to facilitate the translation of these important tools in the study of co-use of cannabis and cigarette smoking.

This study builds on previous studies that employed SC and CC HPTs to examine cigarette and cannabis co-use (Peters et al. 2017; Cooper et al. 2023). Cooper et al. employed SC tasks purchasing cigarette packs and ½ gram joints, and one CC task that price-manipulated ½ a gram joints and offered cigarette packs at a fixed price (\$6) among participants who used cannabis in the past 12 months. About 1 in 5 participants (17%) provided purchasing data that was non-systematic (e.g., illogical demand curves, unrelated to price, etc.) and were eliminated from the analyses. Outliers were top-coded (Cooper et al. 2023). Peters et al. (2017) employed two similar SC tasks using cigarette and cannabis puffs, and two CC tasks, one of which manipulated cigarette puffs and the other manipulated cannabis puffs. Participants used cannabis 20–30 days per month. About 1 in 5 (21.9%) participants' who completed the tasks provided non-systematic (n = 22) or extreme outlier (n = 1) data and were eliminated from the analyses.(Peters et al. 2017) While the analytic procedures in these two studies largely conform to methodological recommendations,(Stein et al. 2015) other forms of validation (e.g., convergent, discriminant, measurement equivalence) are yet to be considered.

The purpose of this study is to extend this work by examining the validity of cigarette and cannabis SC and CC HPTs among adults who smoke cigarettes and cannabis. We administered four HPTs: SC Cigarette, SC Cannabis, CC Cigarette manipulated, and CC Cannabis manipulated HPTs. We limited the route of administration to smoking because smoking is the most prevalent route of cannabis administration among adults and is linked with increased health risks (Quader et al. 2025; McClure et al. 2025; Gallagher et al. 2026). This study *did not* examine purchasing patterns (e.g., substitutes, complements, etc.) because we deemed an examination of the validity of the tasks to be a necessary precursor to evaluating purchasing patterns. We included adults who only smoke cigarettes for comparison purposes. Methodological expectations, hereafter described as methodological validity,(Stein et al. 2015) convergent and discriminant validity,(Wetzel and Killisch 2025) and measurement equivalence (Putnick and Bornstein 2016; Frongillo et al. 2019) were examined. See **Table 1** for hypotheses.

MATERIALS AND METHODS

Participants were adults, ≥ 18 years, who contacted the New York State Quitline (NYSQL) to quit smoking cigarettes. Inclusion criteria were English literacy, smoking at ≥ 8 cigarettes per day (CPD), absence of current Alcohol Use Disorder (i.e., < 15 on the Alcohol Use Disorders Identification Test), (Bohn et al. 1995) having access to an electronic device to complete study tasks. Participants were assigned to the CigOnly group if they reported 0 past-month days of cannabis use (DCU) and the Co-Use group if they reported > 0 past-month DCU. Participants were recruited by mailing and emailing flyers from June 2022 to August 2023.

Procedures. The tasks were administered and all data were collected online using Qualtrics (Provo, UT). All participants were asked to complete all four HPTs. The administration of the SC tasks were randomized followed by randomized administration of the CC tasks.

Measures. Sociodemographics and cigarette-related measures were used to characterize participants including usual number of CPD, age started smoking, years of smoking, and menthol cigarette smoking. The 6-item Fagerstrom Test for Nicotine Dependence (FTND) was used to assess nicotine dependence (Heatherton et al. 1991; Fagerström et al. 2012). Motivation and self-efficacy for smoking cessation were assessed with two items measured on a scale from 0–10 where 0 is “not at all” and 10 is “the most ever”: “How much do you want to quit tobacco?” and “How confident are you that you can quit tobacco and stay quit for good?” (Moolchan et al. 2003; McCarthy et al. 2010). Intentions to quit smoking cigarettes were assessed by asking about plans to quit smoking, last serious quit attempt, and past-month days using smoking cessation medications (i.e, nicotine gum, lozenges, patches, inhaler, Zyban, or Chantix). Cannabis use-related measures included past-month DCU and the Marijuana Dependence Checklist (MDC), a 10-item checklist for assessing past-year marijuana dependence. ([CSL STYLE ERROR: reference with no printed form.]) See **Supplemental Material** for MDC items. Past 30-day levels of psychological distress were assessed with the 6-item Kessler K6 (Kessler et al. 2002, 2011; Prochaska et al. 2012). K6 scores > 4 indicate moderate levels of distress and > 12 indicate serious psychological distress. History of substance use problems was assessed by asking if participants were in recovery from drugs and/or alcohol.

Hypothetical purchase tasks. Prior to each task, participants were instructed to assume that: 1) the available products were their own brand of cigarettes and/or preferred strain of cannabis; 2) they had the same income/savings they have right now; 3) they have no access to other tobacco, nicotine, or cannabis on this day; and 4) they would consume what they purchased within the next 24 hours (Aston and Meshesha 2020; Weinsztok et al. 2023). The smallest unit of cannabis purchasing was one gram, and cigarette purchasing was one cigarette. We limited the timeframe for the consumption of purchases to the next 24 hours to provide a brief, foreseeable temporal window for use. For the SC Cigarette and CC Cigarette manipulated HPT, prices per cigarette were \$0, \$.12, \$.25, \$.50, \$.75, \$1.00, \$2.00, \$4.00, \$8.00. For the SC-Cannabis HPT and CC Cannabis manipulated HPT prices per gram were \$0, \$1.20, \$2.50, \$5.00, \$7.50, \$10.00, \$20.00, \$40.00, \$80.00. The CC Cigarette manipulated HPT offered cannabis at \$10 per gram. The CC Cannabis manipulated HPT offered cigarettes at \$1 per cigarette.

Methodological validity was evaluated in terms of expectations that participant purchasing followed expected, logical patterns; and that the purchases were realistic within the constraints of the task and met expectations about systematicity (Allison 1983; Stein et al. 2015). Outliers were defined as any cigarette or cannabis purchase > 100 units because we assumed that these amounts could not be consumed in 24 hours. Systematicity was quantified according to the three Stein et al. (2015) recommendations: 1) Trend, negligible reductions or increased consumption from the first to last price imposed; 2) Bounce, price-to-price increases in consumption $> 25\%$ of initial consumption; and 3) Reversals, consumption falling to zero and then resuming at higher prices. (Stein et al. 2015) Flat-line responding was deemed consistent with demand law in the assessment of Trend because we expected CigOnly

participants to demonstrate little to no demand for cannabis, an important indicator of discriminant validity, and to accommodate the possibility that participants with low rates of cigarette and/or cannabis use might show little to no price sensitivity within the 24 hour timeframe. Additionally, due to relatively few price points within HPTs, Bounce was defined by a larger percentage (25% vs 10%) than that recommended by Stein et al (2015). (Stein et al. 2015)

Convergent (i.e., the extent to which the tasks measured the concepts they were intended to assess), and *discriminant* validity (i.e., the extent to which the tasks measured unrelated concepts) (Wetzel and Killisch 2025) were evaluated using correlations between demand intensity and relevant measures including the FTND, CPD, the MDC, and past-month DCU. Correlations that were significant or with greater magnitude indicated convergent validity. Weaker or negligible correlations indicated discriminant validity. Flat line purchasing of cannabis by CigOnly participants was also used to indicate discriminant validity.

Measurement equivalence was evaluated by comparing overall convergent and discriminant validity in the total sample. If the overall results were not replicated within the CigOnly and Co-Use groups we suggest measurement non-equivalence (Putnick and Bornstein 2016; Frongillo et al. 2019).

Statistical analysis

Demographic characteristics were summarized using frequency and percentages, means and standard deviations (SD). Differences in demographic characteristics between CigOnly and Co-Use participants were examined using t-tests and Fisher's exact test.

The methodological characteristics of each HPT were described as follows and quantified in proportions: Task non-completion included all participants who initiated, but did not complete a task. Outlier purchases (i.e., > 100 units) were eliminated from further analyses for that task only. Non-systematic responses for Trend, Bounce, and Reversal were determined using the Beezdemand package (Kaplan et al. 2019). The number of participants whose data was eliminated from the analyses of a task were quantified by group and compared using Fisher's exact test.

Demand intensity was calculated among systematic responders using a modified exponential demand model (Koffarnus et al. 2015) $Q = Q_0 * 10^{k(e^{-\alpha Q_0^P} - 1)}$ where Q is the quantity of cigarettes purchased at price P , k is the span of purchased values in logarithmic units, and Q_0 and α are free parameters. Here, we focus on demand intensity Q_0 (i.e., purchasing with no price constraint).

Pearson correlations were conducted among all HPT demand intensities, FTND scores, CPD, MDC scores, and past-month DCU. Convergent and discriminant validity were determined by the magnitude of the correlations. In general, statistical significance indicated convergent validity and non-significance indicated discriminant validity. Significance was set at $\alpha < .05$. See Table 1 for Hypotheses.

Table 1
Study hypotheses

Study hypotheses			
Validity type	Hypothesis	HPT	Criteria
Methodological	1(a) Outlier frequency	All	Minimal number of task completers will show outlier purchasing
	1(b) Systematicity	All	Non-systematic responding rates will be consistent with prior literature
	1(c) Measurement equivalence	All	Outlier frequency and systematicity will not differ between CigOnly and Co-Use participants
Convergent	2(a) Cigarette demand	SC Cigarette	Intensity will be significantly and positively correlated with FTND scores and cigarettes smoked per day.
		CC Cigarette manipulated	
	2(b) Cannabis demand	SC Cannabis	Intensity will be significantly and positively correlated with MDC scores and past-month days of cannabis use.
		CC Cannabis manipulated	
	2(c) Measurement equivalence	All	Convergent validity results found in the total sample will be replicated among CigOnly and Co-Use participants.
	Discriminant	3(a) Cigarette demand	SC Cigarette
CC Cigarette manipulated			
3(b) Cannabis demand		SC Cannabis	Intensity will show non-significant correlations with FTND scores and cigarettes per day.
		CC Cannabis manipulated	
3(c) Measurement equivalence		All	Discriminant validity results found in the total sample will be replicated among CigOnly and Co-Use participants.
HPT= Hypothetical Purchase Task; SC=Single commodity; CC= Cross commodity. Note: CigOnly participants did not endorse any MDC criteria limiting the ability to calculate correlations that include MDC scores among CigOnly participants.			

RESULTS

Participants (n = 124) included n = 22 adults who smoked cigarettes only (CigOnly; 18%) and n = 102 adults who smoked both cigarettes and cannabis (Co-Use; 82%). Participants were, on average, 35.5 (SD 11.4) years old; 41% female, 52% White, and 32% Hispanic. About one-third (37%) were high school graduates; two-thirds (62%) reported household incomes below \$50,000. Most were employed full (48%) or part-time (34%). Participants were highly nicotine dependent with FTND scores on average > 5 and smoked about 18 CPD. About half (48%) smoked menthol cigarettes. Participants were moderately motivated to quit smoking and had relatively low levels of self-efficacy for quitting. Almost half (44%) had no plans to quit smoking in the next 6 months and about one-third (36%) had made a quit attempt in the past 3 months. On average, participants reported moderate levels of psychological distress; 41% were in recovery from other substances. Co-Use participants smoked cannabis, on average, 23.3 (SD 6.7) days per month and scored 6.2 (SD 2.9) on the MDC. See Table 2.

Table 2
Participant characteristics

		Mean (SD) or n (%)		
		Overall (n = 124)	CigOnly (n = 22)	Co-Use (n = 102)
Age***		35.46 (11.4)	45.73 (11.2)	33.18 (10.2)
Female*		51 (41.1)	14 (63.6)	37 (36.3)
Race*	Black or African American	50 (40.3)	2 (9.1)	48 (47.1)
	White	64 (51.6)	18 (81.8)	46 (45.1)
	Other	10 (8.1)	2 (9.1)	9 (8.8)
Hispanic*		40 (32.3)	2 (9.1)	38 (37.3)
Education, yrs completed		18.92 (60.7)	13.33 (4.0)	20.14 (66.9)
Highest grade completed	High School	46 (37.1)	9 (40.9)	37 (36.3)
	College	48 (38.7)	8 (36.4)	40 (39.2)
	Graduate School	30 (24.2)	5 (22.7)	25 (24.5)
Household income	Less than \$24,999	21 (16.9)	3 (13.6)	18 (17.6)
	\$25,000 to \$49,999	56 (45.2)	7 (31.8)	49 (48.0)
	\$50,000 to \$74,999	17 (13.7)	5 (22.7)	12 (11.8)
	More than \$75,000	30 (24.2)	7 (31.8)	23 (22.5)
Basic needs met		6.82 (2.06)	7.38 (2.65)	6.71 (1.92)
Employment status***	Full-time	59 (47.6)	12 (54.5)	47 (46.1)
	Part-time	42 (33.9)	1 (4.5)	41 (40.2)
	Other	23 (18.5)	9 (40.9)	14 (13.7)
Health insurance	Medicare and/or Medicaid	85 (68.5)	10 (45.5)	75 (73.5)
	Private	31 (25.2)	10 (47.6)	21 (20.6)
	None	7 (5.7)	1 (4.8)	6 (5.9)
Partnered		62 (50.0)	13 (59.1)	49 (48.0)
Cigarette smoking related	Cigarettes per day	17.54 (27.06)	16.48 (7.48)	17.77 (29.63)
	FTND score	5.18 (1.75)	5.48 (2.14)	5.12 (1.66)
	Smokes menthol cigarettes	58 (48.3)	9 (42.9)	49 (49.5)

*p<.05; **p<.01, ***p<.001; MDC=Marijuana Dependence Checklist; Age is missing 3 observations; Education, yrs completed, Basic needs met, Health insurance, Past month cannabis use days, Past month other cannabis use days, and In SUD recovery are missing 1 observation each; Cigarettes per day, Medication use, Age started smoking cigarettes, Yrs cigarette smoking, FTND, Plans to quit smoking cigarettes, Last serious quit attempt, and Smoked menthol cigarettes are missing 4 observations; Age started smoking cigarettes is 5 missing observations; MDC Score, Motivation, Self-efficacy, and Psychological distress are missing 9 observations.

		Mean (SD) or n (%)		
		Overall (n = 124)	CigOnly (n = 22)	Co-Use (n = 102)
	Age started smoking cigarettes	17.92 (4.48)	19.52 (8.02)	17.57 (3.24)
	Yrs smoking cigarettes***	13.51 (10.79)	23.12 (12.76)	11.47 (9.17)
	Motivation to quit smoking*	5.27 (3.25)	6.80 (2.95)	4.95 (3.24)
	Self-efficacy to quit smoking	4.49 (3.16)	4.45 (3.73)	4.49 (3.05)
Plans to quit smoking cigarettes	Yes, within the next 30 days	43 (35.8)	6 (28.6)	37 (37.4)
	Yes, within the next 6 months	24 (20.0)	5 (23.8)	19 (19.2)
	Not within the next 6 months	53 (44.2)	10 (47.6)	43 (43.4)
Last serious quit attempt**	Within the past 3 months	43 (35.8)	3 (14.3)	40 (40.4)
	Within the past year	26 (21.7)	8 (38.1)	18 (18.2)
	More than 1 year ago	33 (27.5)	10 (47.6)	23 (23.2)
	Never	18 (15.0)	0 (0.0)	18 (18.2)
Past-month days using medications for smoking cessation*		3.03 (6.91)	0.14 (0.65)	3.65 (7.46)
Psychological distress level (K6)*		9.83 (5.48)	7.45 (5.48)	10.34 (5.37)
In recovery from SUDs*		50 (40.7)	3 (14.3)	47 (46.1)
Past month cannabis use days	Cannabis smoking days***	19.33 (10.71)	0.00 (0.00)	23.31 (6.69)
	Other cannabis use days***	6.55 (9.69)	0.10 (0.44)	7.88 (10.15)
	MDC score***	4.99 (3.58)	0.00 (0.00)	6.17 (2.91)
*p<.05; **p<.01, ***p<.001; MDC=Marijuana Dependence Checklist; Age is missing 3 observations; Education, yrs completed, Basic needs met, Health insurance, Past month cannabis use days, Past month other cannabis use days, and In SUD recovery are missing 1 observation each; Cigarettes per day, Medication use, Age started smoking cigarettes, Yrs cigarette smoking, FTND, Plans to quit smoking cigarettes, Last serious quit attempt, and Smoked menthol cigarettes are missing 4 observations; Age started smoking cigarettes is 5 missing observations; MDC Score, Motivation, Self-efficacy, and Psychological distress are missing 9 observations.				

Co-Use participants were significantly younger ($p<.001$), more likely to be male ($p=.033$), Black or African American and/or Hispanic ($p=.021$), and employed full- or part-time ($p=.001$) compared to CigOnly participants. Co-Use participants smoked cigarettes for fewer years ($p<.001$), likely because of younger age. Co-Use participants used smoking cessation medications for more days in the past-month ($p=.034$), but overall use of medications was low. Co-Use participants had significantly higher levels of psychological distress ($p=.032$), but both groups' scores were in the moderate range. Co-Use participants were significantly more likely to be in recovery from other substances than

CigOnly participants ($p=.014$) and more likely to have made a recent quit attempt than CigOnly participants. See Table 2.

Single Commodity Cigarette Purchase Task

Overall, $n = 20$ (91%) of the CigOnly and $n = 87$ (85%) of the Co-Use participants completed the SC-Cigarette HPT.

Methodological validity. Hypotheses: **1(a)** Two ($n = 2$) participants showed outlier purchasing and were eliminated from additional analyses. **1(b)** Among remaining participants ($n = 105$), non-systematic responses ($n = 17$) from $n = 11$ participants included $n = 6$ that violated Trend, $n = 9$ that violated Bounce, and $n = 2$ Reversals, leaving $n = 94$ included in the analyses. **1(c)** Roughly the same proportion of CigOnly ($n = 2$; 10%) and Co-Use ($n = 11$; 13%) participants were eliminated due to outlier and/or non-systematic responding ($p>.999$). See Table 3.

Table 3
Outlier and systematicity methodological criteria applied to each purchase task

Hypothetical purchase task type	CigOnly (n = 22)	Co-Use (n = 102)	Excluded total (n)		Non-systematic responses, number and type			Excluded by group	
			Task completers (n)	Outliers ¹ (n)	Non-systematic responding (n)	T ²	B ³	R ⁴	CigOnly (n, % of CigOnly task completers)
SC Cigarette	20	87	2	11	6	9	2	2 (10.0)	11 (12.6) ^a
SC Cannabis	20	87	2	8	5	7	2	0 (0) ⁵	10 (11.5) ^b
CC Cigarette manipulated	20	81	4	9	4	9	2	3 (15.0)	10 (12.3) ^c
CC Cannabis manipulated	20	81	3	21	15	10	1	0 (0) ⁵	24 (29.6)^d
CigOnly=participants who smoked cannabis 0 days in the past 30 days at screening; CoUse=participants who smoked cannabis > 0 days in the past 30 days at screening; CgPT=cigarette purchase task; CaPt=cannabis purchase task; CgCa-Ca manipulated=cross-commodity cigarette-cannabis purchase task where cannabis price is manipulated; CaCg-Cg manipulated=cross-commodity cigarette-cannabis purchase task where cigarette price is manipulated; *A total of 6 participants made all the outlier purchasing across the four tasks; ¹ Outliers = Participants who purchased > 100 units at any given price; ² T = Trend; ³ B = Bounce (< 25%); ⁴ R = Reversals; ⁵ n = 18 CigOnly participants displayed no cannabis purchasing in these tasks. Statistical significance of proportion of participants excluded by group: ^a p=.999; ^b p=.203; ^c p=.718; ^d p=.003 (Bold).									

Convergent validity. Hypotheses: **2(a)** The intensity of cigarette demand was significantly positively correlated with FTND scores ($r = 0.44$; $p<.001$) and CPD ($r = 0.56$; $p<.001$), supporting convergent validity. **2(c)** These significant positive associations were found among both CigOnly and Co-Use participants, supporting measurement equivalence for convergent validity. See Table 4, S4-1, and S4-2.

Table 4

Pearson correlations between demand intensities for each hypothetical purchase task and measures of nicotine and cannabis dependence, all participants (n = 124)

	Demand intensity				Nicotine dependence		Cannabis dependence	
	HPT	SC Cannabis	CC Cigarette manipulated	CC Cannabis manipulated	FTND	CPD	MDC	DCU
Demand intensity	SC Cigarette	0.00	0.52****	0.05	0.44****	0.56****	-0.03	0.02
	SC Cannabis	–	0.12	0.77****	-0.02	0.08	0.25*	0.24*
	CC Cigarette manipulated	–	–	0.24*	0.30**	0.34**	-0.09	-0.10
	CC Cannabis manipulated	–	–	–	-0.14	-0.06	0.11	0.18
Nicotine dependence	FTND	–	–	–	–	0.13	0.15	-0.03
	CPD	–	–	–	–	–	0.09	0.00
Cannabis dependence	MDC	–	–	–	–	–	–	0.54****
*p < 0.05, **p < 0.01, ***p < 0.001, ****p < 0.0001; CC= Cross commodity; FTND= Fagerstrom Test for Nicotine Dependence; CPD= Usual number of cigarettes per day; MDC = Marijuana Dependence Checklist; DCU = Past month days of cannabis use.								

Discriminant validity. Hypotheses: **3(a)** The intensity of cigarette demand was not significantly correlated with MDC scores ($r = -.03, p = .747$) or past-month DCU ($r = .02, p = .825$), supporting discriminant validity. **3(c)** Among Co-Use participants, the intensity of cigarette demand was not significantly correlated with MDC scores ($r = .05, p = .671$) and past-month DCU ($r = .22, p = .052$), supporting measurement equivalence for discriminant validity among Co-Use participants. CigOnly participants did not endorse any MDC criteria or cannabis use days limiting the ability to replicate discriminant validity results in the CigOnly group. See Table 4, S4-1, and S4-2.

Single Commodity Cannabis Purchase Task

Overall, n = 20 (91%) of the CigOnly and n = 87 (85%) of the Co-Use participants completed the SC-Cannabis HPT.

Methodological validity. Hypotheses: **1(a)** Two (2) participants displayed outlier purchasing and were eliminated from additional analyses. **1(b)** Among remaining participants (n = 105), non-systematic responses (n = 14) from n = 8 participants included n = 5 responses that violated Trend, n = 7 that violated Bounce, and n = 2 that displayed Reversals, leaving n = 97 included in the analyses. **1(c)** None of the CigOnly and n = 10 (11.5%) of the Co-Use participants were eliminated due to extreme outlier and/or non-systematic responses, but this was not statistically different ($p = .203$). See Table 3.

Convergent validity. Hypotheses: **2(b)** The intensity of cannabis purchasing was significantly positively associated with MDC scores ($r = 0.25; p = .014$) and past-month DCU ($r = 0.24; p = .018$), supporting convergent validity. **2(c)** The

significance of this correlation, however, was dependent on the inclusion of the variability contributed by the CigOnly participants, who all scored zero on the MDC. Contrary to hypotheses, among Co-Use participants, significant correlations between the intensity of cannabis purchasing and MDC scores ($r = 0.08, p = .475$) and past-month DCU ($r = -.03, p = .802$) were not found, supporting measurement non-equivalence for convergent validity. See Table 4, S4-1, and S4-2.

Discriminant Validity. Hypotheses: **3(b)** The intensity of cannabis demand was not significantly correlated with FTND scores ($r = -.02, p = .821$) and CPD ($r = .08, p = .423$), supporting discriminant validity. **3(c)** Among CigOnly participants and Co-Use participants, the intensity of cannabis demand was not significantly correlated with FTND scores and CPD, supporting measurement equivalence for discriminant validity: CigOnly: FTND; $r = -.02; p = .82$ and CPD $r = .08; p = .42$; Co-Use: FTND $r = .12; p = .307$) and CPD ($r = .09; p = .421$). Note that $n = 18$ CigOnly participants purchased no cannabis in this task. See Table 4, S4-1, and S4-2.

Cross-Commodity Cigarette Manipulated Purchase Task

Overall, $n = 20$ (91%) of the CigOnly and $n = 81$ (79%) of the Co-Use participants completed the CC-Cigarette Manipulated HPT.

Methodological Validity. Hypotheses: **1(a)** Four ($n = 4$) participants showed outlier purchasing and were eliminated from additional analyses. **1(b)** Among remaining participants, ($n = 97$), non-systematic responses ($n = 15$) from $n = 9$ participants included $n = 4$ responses that violated Trend, $n = 9$ that violated Bounce, and $n = 2$ Reversals, leaving $n = 84$ included in the analyses. **1(c)** Roughly the same proportion of CigOnly ($n = 3, 15\%$) and Co-Use ($n = 10, 12\%$) participants were eliminated due to extreme outlier and/or non-systematic responding ($p = .718$). See Table 3.

Convergent validity. Hypotheses: **2(a)** The intensity of cigarette demand was significantly positively correlated with FTND scores ($r = 0.30; p = .004$) and CPD ($r = 0.34; p = .001$), supporting convergent validity. **2(c)** Among Co-Use participants, cigarette demand intensity was significantly positively correlated with FTND scores ($r = .32, p = .007$) and CPD ($r = .33, p = .005$). Among CigOnly participants, cigarette demand intensity was not significantly correlated with FTND scores ($r = .23, p = .379$) and CPD ($r = .47, p = .058$), however, the magnitude of these correlations were similar to those found in the total supporting measurement equivalence among CigOnly participants for this task. The CigOnly group ($n = 22$) was likely under-powered for significance testing. See Table 4, S4-1, and S4-2.

Discriminant validity. Hypotheses: **3(a)** The intensity of cigarette demand was not significantly correlated with MDC scores ($r = .11, p = .364$) and past-month DCU ($r = .18, p = .116$), supporting discriminant validity. **3(c)** Among Co-Use participants, the intensity of cigarette demand was not significantly correlated MDC; $r = -.01, p = .929$) and past-month DCU ($r = .00, p = .993$), supporting measurement equivalence. See Table 4, S4-1, and S4-2.

Cross-Commodity Cannabis Manipulated Purchase Task

Overall, $n = 20$ (91%) of the CigOnly and $n = 81$ (79%) of the Co-Use participants completed this CC task.

Methodological validity. Hypotheses: **1(a)** Three ($n = 3$) participants showed outlier purchasing and were eliminated from additional analyses. **1(b)** Among participants who made purchases within a reasonable range ($n = 98$), non-systematic responses ($n = 26$) from $n = 21$ participants included $n = 15$ responses that violated Trend, $n = 10$ responses that violated Bounce, and $n = 1$ Reversal, leaving $n = 77$ included in the analyses. **1(c)** Significantly different

rates of CigOnly ($n = 0, 0\%$) and Co-Use ($n = 24, 30\%$) participants were eliminated due to extreme outlier and/or non-systematic responding ($p=.003$). See Table 3.

Convergent validity. Hypotheses: **2(b)** Contrary to hypotheses, the intensity of cannabis demand was not significantly correlated with MDC scores ($r=.11$; $p=.364$), or past-month DCU ($r=.18$; $p=.116$), lacking support for convergent validity. **2(c)** Similarly, among Co-Use participants, the intensity of cannabis demand was not significantly correlated with MDC scores ($r=-.02$; $p=.905$) or past-month DCU ($r=.09$; $p=.527$), suggesting measurement equivalence. See Table 4, S4-1, and S4-2.

Discriminant validity. Hypotheses: **3(b)** The intensity of cannabis demand was not significantly correlated with FTND scores ($r=-.14$; $p=.232$) and CPD ($r=-.06$; $p=.619$), supporting discriminant validity. **3(c)** Among both CigOnly and Co-Use participants, the intensity of cannabis demand was not significantly correlated with FTND scores and CPD, suggesting measurement equivalence for discriminant validity for this task (CigOnly FTND, $r=-.40$; $p=.082$ and CPD $r=-.27$; $p=.243$; Co-Use FTND, $r=.01$; $p=.958$ and CPD $r=.05$; $p=.713$). Note: $n = 18$ CigOnly participants displayed no cannabis purchasing in this task. See Tables 4, S4-1, and S4-2.

DISCUSSION

These findings represent the first formal examination of the systematicity, validity, and measurement equivalence of SC and CC Cigarette and Cannabis HPTs among participants who smoke cigarettes and cannabis. All HPTs showed reasonable methodological, convergent, discriminant validity, and/or measurement equivalence with a few important caveats. These findings also provide an initial framework for the evaluation of the psychometric qualities of HPTs in new populations.

The SC HPTs and the CC Cigarette manipulated HPT showed rates of non-systematic responding similar to previous studies (Peters et al. 2017; Cooper et al. 2023). However, the CC Cannabis manipulated task showed higher rates of non-systematic responding, performed entirely by Co-Use participants. Co-Use participants were less likely to complete HPTs (79–84% versus 91%) and more likely to be excluded for non-systematic responses on both CC tasks (12–30% versus 0%) than CigOnly participants. All outlier purchases across all HPTs were performed by Co-Use participants.

Although all participants were former Quitline enrollees, Co-Use and CigOnly characteristics differed, which may have contributed to performance differences in an unknown manner. Future research should examine whether people who co-use cigarettes and cannabis consistently show high rates of non-systematic responding, and if so, examine strategies for ameliorating the issues. Automated verification, data validation, or confirmation checks (e.g., Are you sure you can smoke [x] in 24 hours?) might improve systematic responding. Systematically excluding data from people with the same demographic profiles should be addressed because it can create sampling bias (Gelino et al. 2026).

The SC Cigarette HPT is well-established, having shown convergent and discriminant validity among college students and predictive validity among people with other SUDs (Jacobs and Bickel 1999; MacKillop et al. 2008; MacKillop et al. 2016). Our findings add to this evidence by showing validity and measurement equivalence among NYSQL enrollees. The strong systematicity, validity, and measurement equivalence for this task is likely due to highly relatable purchase units (e.g., 1 cigarette) and convergent validity measures that are robustly associated with cigarette demand in other studies (e.g., FTND, CPD) (González-Roz et al. 2019).

Overall, the SC Cannabis HPT showed good methodological, convergent, and discriminant validity, consistent with previous findings (Aston and Meshesha 2020). In addition, 90% of CigOnly participants purchased no cannabis, providing additional evidence that the task is measuring the perceived value of cannabis. However, these results relied on the variability contributed by the CigOnly participants, who all scored zero on the MDC and had no past-month DCU, increasing the slope of the linear relation. This suggests that the MDC and past-month DCU are only useful for assessing convergent validity when there is sufficient variability in cannabis smoking among participants, which is not ideal.

Although the CC Cannabis manipulated HPT showed discriminant validity, it failed to show convergent validity overall and among Co-Use participants. The lack of variability in the MDC and past-month DCU again contributed to the lack of significance. Interestingly, among Co-Use participants, the difference in cannabis demand between the SC and CC Cannabis HPTs showed a reduction in the intensity of demand in the presence of cigarettes by 7.17 units (results not shown), suggesting that when purchasing cannabis competes with purchasing cigarettes, participants purchased less cannabis.

More research is needed to establish convergent validity and measurement equivalence for SC and CC Cannabis HPTs, to ensure HPTs are using highly relatable units relevant to use timeframes, and to more effectively quantify cannabis use among participants. While grams reflect real-world purchasing of pre-rolled joints, (Aston and Meshesha 2020) grams might not reflect meaningful, real-world units of 24-hour use among Co-Use participants in this study. A one gram joint is relatively large and the amount of grams smoked per day is unknown. Also, the MDC and past-month DCU might not be granular enough or measure similar enough constructs to cannabis demand. A reason why the FTND is so consistently correlated with cigarette demand might be because the FTND is not based on clinical criteria for nicotine dependence, and thus might measure a different aspect of dependence than measures linked to substance use diagnoses.

The CC Cigarette manipulated HPT showed good overall convergent and discriminant validity with measurement equivalence among Co-Use participants. While convergent measurement equivalence did not achieve statistical significance among the CigOnly participants, the magnitude of correlations among CigOnly participants, FTND ($r = 0.23$) and CPD ($r = 0.47$), were similar to those observed in the total sample ($r = 0.30$ and 0.34 respectively) and among Co-Use participants ($r = .32$ and $r = .33$ respectively), suggesting a lack of power. Nonetheless, the lack of statistical significance should be investigated further.

These findings should be considered in the context of several limitations including the selection of measures used to assess convergent validity for cannabis demand. Participants who have enrolled in the NYSQL might not represent all people in the US. Finally, all tasks were hypothetical and completed remotely and might not compare with real-world purchasing and HPTs conducted in laboratory settings.

CONCLUSION

SC Cigarette and Cannabis HPTs show reasonable systematicity, convergent and discriminant validity, and measurement equivalence among people who co-use cigarettes and cannabis; however, the SC Cannabis HPT failed to show convergent measurement equivalence among Co-Use participants and the CC Cannabis manipulated HPT failed to show convergent validity with measures of cannabis dependence. Co-Use participants appeared to experience barriers to completing the HPTs and providing systematic responses. Careful consideration of the psychometric qualities of HPTs within specific populations is needed to facilitate the translation of these important tools in the study of the relations between cannabis and cigarette smoking.

Declarations

Compliance with Ethical Standards.

This study received ethical approval from the Institutional Review Boards (IRBs) at Roswell Park Comprehensive Cancer Center, Buffalo, NY, USA and Virginia Polytechnical Institute and State University, Roanoke, VA, USA. The Roswell Park Institutional Review Board served as the primary IRB for this research. Accordingly, this study was conducted in accordance with the World Medical Association Declaration of Helsinki Ethical Principles for Medical Research involving Human Participants, October 2024. All participants provided informed consent prior to participating in this research.

Declarations.

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Author Contribution

Conceptualization: CS and AT formulated the research goals and aims. Data curation: CE, TN, SX, and AT managed the data activities. Formal analysis: AT and SX conducted the formal analyses. AT and CS developed the design and the methodology. Methodology: CS and TN developed the methodology. Project administration: CS, TN, and TN coordinated the research activities. Resources: CS provided the research materials and resources. Supervision: CS and AT led the research activity planning and execution, including mentorship of other team members. Writing - original draft: CS, AT, and TN wrote the first draft. Writing - review and editing: All authors reviewed the manuscript and provided substantive contributions to the manuscript.

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Data Availability

Data from this study are available by reasonable request to the corresponding author.

References

1. Agrawal A, Budney AJ, Lynskey MT (2012) The co-occurring use and misuse of cannabis and tobacco: a review. *Addiction* 107:1221–1233. <https://doi.org/10.1111/j.1360-0443.2012.03837.x>
2. Allison J (1983) Behavioral substitutes and complements. *Advances in Psychology*. Elsevier, pp 1–30

3. Aston ER, Meshesha LZ (2020) Assessing cannabis demand: A comprehensive review of the marijuana purchase task. *Neurotherapeutics* 17:87–99. <https://doi.org/10.1007/s13311-019-00819-z>
4. Bickel WK, DeGrandpre RJ, Higgins ST (1995) The behavioral economics of concurrent drug reinforcers: a review and reanalysis of drug self-administration research. *Psychopharmacology* 118:250–259. <https://doi.org/10.1007/bf02245952>
5. Bohn MJ, Babor TF, Kranzler HR (1995) The Alcohol Use Disorders Identification Test (AUDIT): validation of a screening instrument for use in medical settings. *J Stud Alcohol* 56:423–432. <https://doi.org/10.15288/jsa.1995.56.423>
6. Britton M, Haddad S, Derrick JL (2020) Prospective and Daily Effects of Cannabis Use on Smoking Outcomes During a Self-Guided Quit Attempt. *Nicotine Tob Res* 22:1399–1403. <https://doi.org/10.1093/ntr/ntaa083>
7. Cooper M, Panchalingam T, Ce S, Shi Y (2023) Behavioral economic relationship between cannabis and cigarettes: Evidence from hypothetical purchase tasks. *Int J Drug Policy* 112:103951. <https://doi.org/10.1016/j.drugpo.2022.103951>
8. Dave DM, Liang Y, Pesko MF, Phillips S, Sabia JJ (2022) Have Recreational Marijuana Laws Undermined Public Health Progress. on Adult Tobacco Use? National Bureau of Economic Research
9. Fagerström K, Russ C, Yu C-R et al (2012) The Fagerström Test for Nicotine Dependence as a predictor of smoking abstinence: a pooled analysis of varenicline clinical trial data. *Nicotine Tob Res* 14:1467–1473. <https://doi.org/10.1093/ntr/nts018>
10. Ferguson E, Bush N, Yurasek A, Boissoneault J (2021) The effect of next day responsibilities and an adaptive purchase task on cannabis demand. *Drug Alcohol Depend* 227:108919. <https://doi.org/10.1016/j.drugalcdep.2021.108919>
11. Fiore MC, Jaén CR, Baker TB et al (2008) Treating tobacco use and dependence: 2008 update. US Department of Health and Human Services, Rockville, MD
12. Frongillo EA, Baranowski T, Subar AF et al (2019) Establishing validity and cross-context equivalence of measures and indicators. *J Acad Nutr Diet* 119:1817–1830. <https://doi.org/10.1016/j.jand.2018.09.005>
13. Gallagher TJ, Kokot NC, Lopez J et al (2026) Association of cannabis use and lung cancer: a retrospective cohort study. *Lung Cancer* 216:109421. <https://doi.org/10.1016/j.lungcan.2026.109421>
14. Gelino BW, Felton JW, Hung I-T et al (2026) Delay discounting violations vary by adolescent sociodemographics: Excluding nonsystematic data may bias conclusions. *Exp Clin Psychopharmacol* 34:31–43. <https://doi.org/10.1037/pha0000809>
15. González-Roz A, Jackson J, Murphy C et al (2019) Behavioral economic tobacco demand in relation to cigarette consumption and nicotine dependence: a meta-analysis of cross-sectional relationships. *Addiction* 114:1926–1940. <https://doi.org/10.1111/add.14736>
16. Goodwin RD, Pacek LR, Copeland J et al (2018) Trends in Daily Cannabis Use Among Cigarette Smokers: United States, 2002–2014. *Am J Public Health* 108:137–142. <https://doi.org/10.2105/AJPH.2017.304050>
17. Goodwin RD, Shevorykin A, Carl E et al (2022) Daily cannabis use is a barrier to tobacco cessation among tobacco quitline callers at 7-month follow-up. *Nicotine Tob Res*. <https://doi.org/10.1093/ntr/ntac096>
18. Han BH, Palamar JJ (2020) Trends in Cannabis Use Among Older Adults in the United States, 2015–2018. *JAMA Intern Med* 180:609–611. <https://doi.org/10.1001/jamainternmed.2019.7517>
19. Heatherton TF, Kozlowski LT, Frecker RC, Fagerström KO (1991) The Fagerström Test for Nicotine Dependence: A revision of the Fagerström Tolerance Questionnaire. *Br J Addict* 86:1119–1127

20. Hursh SR, Madden GJ, Spiga R et al (2013) The translational utility of behavioral economics: The experimental analysis of consumption and choice. In: APA handbook of behavior analysis, Vol. 2: Translating principles into practice. American Psychological Association, Washington, pp 191–224
21. Jacobs EA, Bickel WK (1999) Modeling drug consumption in the clinic using simulation procedures: demand for heroin and cigarettes in opioid-dependent outpatients. *Exp Clin Psychopharmacol* 7:412–426. <https://doi.org/10.1037//1064-1297.7.4.412>
22. Kaplan BA, Gilroy SP, Reed DD et al (2019) The R package beezdemand: Behavioral Economic Easy Demand. *Perspect Behav Sci* 42:163–180. <https://doi.org/10.1007/s40614-018-00187-7>
23. Kessler RC, Andrews G, Colpe LJ et al (2002) Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med* 32:959–976. <https://doi.org/10.1017/s0033291702006074>
24. Kessler RC, Green JG, Gruber MJ et al (2011) Screening for serious mental illness in the general population with the K6 screening scale: results from the WHO World Mental Health (WMH) survey initiative. *Int J Methods Psychiatr Res* 20:62–62. <https://doi.org/10.1002/mpr.333>
25. Koffarnus MN, Franck CT, Stein JS, Bickel WK (2015) A modified exponential behavioral economic demand model to better describe consumption data. *Exp Clin Psychopharmacol* 23:504–512. <https://doi.org/10.1037/pha0000045>
26. Mackillop J, Murphy CM, Martin RA et al (2016) Predictive validity of a cigarette purchase task in a randomized controlled trial of contingent vouchers for smoking in individuals with substance use disorders. *Nicotine Tob Res* 18:531–537. <https://doi.org/10.1093/ntr/ntv233>
27. MacKillop J, Murphy JG, Ray LA et al (2008) Further validation of a cigarette purchase task for assessing the relative reinforcing efficacy of nicotine in college smokers. *Exp Clin Psychopharmacol* 16:57–65. <https://doi.org/10.1037/1064-1297.16.1.57>
28. McCarthy DE, Piasecki TM, Jorenby DE et al (2010) A multi-level analysis of nonsignificant counseling effects in a randomized smoking cessation trial. *Addiction* 105:2195–2208
29. McClure EA, Piper ME, Crotty Alexander LE et al (2025) Effects of inhaled tobacco and cannabis co-use on respiratory health and tobacco cessation: An official American thoracic society research statement. *Am J Respir Crit Care Med* 211:2021–2042. <https://doi.org/10.1164/rccm.202507-1792ST>
30. McClure EA, Rabin RA, Lee DC, Hindocha C (2020) Treatment Implications Associated with Cannabis and Tobacco Co-Use. *Curr Addict Rep* 7:533–544. <https://doi.org/10.1007/s40429-020-00334-8>
31. McClure EA, Tomko RL, Salazar CA et al (2019) Tobacco and cannabis co-use: Drug substitution, quit interest, and cessation preferences. *Exp Clin Psychopharmacol* 27:265–275. <https://doi.org/10.1037/pha0000244>
32. Moolchan ET, Berlin I, Robinson ML, Cadet JL (2003) Characteristics of African American teenage smokers who request cessation treatment: implications for addressing health disparities. *Arch Pediatr Adolesc Med* 157:533–538. <https://doi.org/10.1001/archpedi.157.6.533>
33. National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health (2014) The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General. Centers for Disease Control and Prevention (US). Atlanta (GA)
34. Nguyen N, Bold KW, McClure EA (2024) Urgent need for treatment addressing co-use of tobacco and cannabis: An updated review and considerations for future interventions. *Addict Behav* 158:108118. <https://doi.org/10.1016/j.addbeh.2024.108118>

35. NIDA (2022) Marijuana and hallucinogen use among young adults reached all time-high in 2021. August 22, 2022 Accessed August 4, 2023. In: National Institute on Drug Abuse website. <https://nida.nih.gov/news-events/news-releases/2022/08/marijuana-and-hallucinogen-use-among-young-adults-reached-all-time-high-in-2021>. Accessed 4 Aug 2023
36. Nighbor TD, Zvorsky I, Kurti AN et al (2019) Examining interrelationships between the Cigarette Purchase Task and delay discounting among pregnant women. *J Exp Anal Behav* 111:405–415. <https://doi.org/10.1002/jeab.499>
37. Peters EN, Herrmann ES, Smith C et al (2021) Impact of smoked cannabis on tobacco cigarette smoking intensity and subjective effects: A placebo-controlled, double-blind, within-subjects human laboratory study. *Exp Clin Psychopharmacol* 29:345–354. <https://doi.org/10.1037/pha0000391>
38. Peters EN, Rosenberry ZR, Schauer GL et al (2017) Marijuana and tobacco cigarettes: Estimating their behavioral economic relationship using purchasing tasks. *Exp Clin Psychopharmacol* 25:208–215. <https://doi.org/10.1037/pha0000122>
39. Prochaska JJ, Sung H-Y, Max W et al (2012) Validity study of the K6 scale as a measure of moderate mental distress based on mental health treatment need and utilization. *Int J Methods Psychiatr Res* 21:88–97. <https://doi.org/10.1002/mpr.1349>
40. Putnick DL, Bornstein MH (2016) Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Dev Rev* 41:71–90. <https://doi.org/10.1016/j.dr.2016.06.004>
41. Quader ZS, Roehler DR, Vivolo-Kantor AM, Ko JY (2025) Routes of marijuana use - Behavioral Risk Factor Surveillance System, 22 U.S. states and two territories, 2022. *MMWR Morb Mortal Wkly Rep* 74:198–204. <https://doi.org/10.15585/mmwr.mm7412a1>
42. Rabin RA, George TP (2015) A review of co-morbid tobacco and cannabis use disorders: possible mechanisms to explain high rates of co-use. *Am J Addict* 24:105–116. <https://doi.org/10.1111/ajad.12186>
43. Roma PG, Reed DD, DiGennaro Reed FD, Hursh SR (2017) Progress of and prospects for hypothetical purchase task questionnaires in consumer behavior analysis and public policy. *Behav Anal* 40:329–342. <https://doi.org/10.1007/s40614-017-0100-2>
44. Rubenstein D, McClernon FJ, Pacek LR (2024) Trends in cannabis and tobacco co-use in the United States, 2002–2021. *Addict Behav* 158:108129. <https://doi.org/10.1016/j.addbeh.2024.108129>
45. Rubinstein ML, Rait MA, Prochaska JJ (2014) Frequent marijuana use is associated with greater nicotine addiction in adolescent smokers. *Drug Alcohol Depend* 141:159–162. <https://doi.org/10.1016/j.drugalcdep.2014.05.015>
46. Scherma M, Fadda P, Le Foll B et al (2008) The endocannabinoid system: a new molecular target for the treatment of tobacco addiction. *CNS Neurol Disord Drug Targets* 7:468–481. <https://doi.org/10.2174/187152708786927859>
47. Scherma M, Muntoni AL, Melis M et al (2016) Interactions between the endocannabinoid and nicotinic cholinergic systems: preclinical evidence and therapeutic perspectives. *Psychopharmacology* 233:1765–1777. <https://doi.org/10.1007/s00213-015-4196-3>
48. Stein JS, Koffarnus MN, Snider SE et al (2015) Identification and management of nonsystematic purchase task data: Toward best practice. *Exp Clin Psychopharmacol* 23:377–386. <https://doi.org/10.1037/pha0000020>
49. Strickland JC, Campbell EM, Lile JA, Stoops WW (2020) Utilizing the commodity purchase task to evaluate behavioral economic demand for illicit substances: a review and meta-analysis. *Addiction* 115:393–406. <https://doi.org/10.1111/add.14792>

50. Subramaniam P, McGlade E, Yurgelun-Todd D (2016) Comorbid Cannabis and Tobacco Use in Adolescents and Adults. *Curr Addict Rep* 3:182–188. <https://doi.org/10.1007/s40429-016-0101-3>
51. Substance Abuse and Mental Health Services Administration (2021) Key substance use and mental health indicators in the United States: Results from the 2020 National Survey on Drug Use and Health (HHS Publication No. PEP21-07-01-003, NSDUH Series H-56). Substance Abuse and Mental Health Services Administration
52. Swan K, Speyer R, Scharitzer M et al (2023) Measuring what matters in healthcare: a practical guide to psychometric principles and instrument development. *Front Psychol* 14:1225850. <https://doi.org/10.3389/fpsyg.2023.1225850>
53. Tullis LM, Dupont R, Frost-Pineda K, Gold MS (2003) Marijuana and tobacco: a major connection? *J Addict Dis* 22:51–62. https://doi.org/10.1300/J069v22n03_05
54. Weinberger AH, Delnevo CD, Wyka K et al (2020) Cannabis Use Is Associated With Increased Risk of Cigarette Smoking Initiation, Persistence, and Relapse Among Adults in the United States. *Nicotine Tob Res* 22:1404–1408. <https://doi.org/10.1093/ntr/ntz085>
55. Weinberger AH, Platt J, Zhu J et al (2021) Cigarette Use and Cannabis Use Disorder Onset, Persistence, and Relapse: Longitudinal Data From a Representative Sample of US Adults. *J Clin Psychiatry* 82. <https://doi.org/10.4088/JCP.20m13713>
56. Weinberger AH, Wyka K, Kim JH et al (2022) A difference-in-difference approach to examining the impact of cannabis legalization on disparities in the use of cigarettes and cannabis in the United States, 2004–17. *Addiction* 117:1768–1777. <https://doi.org/10.1111/add.15795>
57. Weinsztok SC, Reed DD, Amlung M (2023) Substance-related cross-commodity purchase tasks: A systematic review. *Psychol Addict Behav* 37:72–86. <https://doi.org/10.1037/adb0000851>
58. Wetzel E, Killisch J (2025) Testing convergent and discriminant validity using a Priori defined hypotheses. *Eur J Psychol Assess* 41:253–256. <https://doi.org/10.1027/1015-5759/a000918>
59. Xue Z, Gibson LP, Nighbor T et al (2026) Prevalence, patterns, and correlates of cannabis-cigarette co-use: Findings from a multi-state rapid-response survey in the U.s., 2023–2024. *Am J Prev Med* 70:108114. <https://doi.org/10.1016/j.amepre.2025.108114>
60. Marijuana Dependence Checklist (MDC) In: University of Wisconsin-Madison Addiction Research Center. <https://arc.psych.wisc.edu/self-report/marijuana-dependence-checklist-mdc/>. Accessed 19 Jun 2026

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