



## Intention to quit or reduce e-cigarettes, cannabis, and their co-use among a school-based sample of adolescents

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### ABSTRACT

**Introduction:** Little is known about the prevalence and predictors of adolescents' intention to quit or reduce use of e-cigarettes and/or cannabis.

**Methods:** Frequencies of intention to change (quit, reduce) e-cigarettes and/or cannabis use were examined among 23,915 surveyed middle and high school students with sole and co-use. Predictors of intention to change were identified via LASSO/multilevel logistic regression.

**Results:** Among those with sole e-cigarette use ( $n = 543$ ), 40.9 % intended to quit and 24.1 % intended to reduce; non-daily e-cigarette use predicted intention to quit and reduce e-cigarettes ( $p$ 's  $< 0.03$ ). Among those with sole cannabis use ( $n = 546$ ), 10.6 % intended to quit and 25.1 % intended to reduce; absence of cannabis cravings predicted intention to reduce cannabis use ( $p < 0.01$ ). Among those with co-use ( $n = 816$ ), 26.2 % intended to either quit or reduce (quit/reduce) both substances, 27.5 % intended to quit/reduce e-cigarettes only, and 6.9 % intended to quit/reduce cannabis only. No predictors emerged for intention to change e-cigarette use among those with co-use ( $p$ 's  $> 0.09$ ), but younger age, lack of poly-tobacco use, and lack of cannabis craving predicted intention to quit/reduce cannabis use ( $p$ 's  $< 0.04$ ).

**Conclusions:** More than half of adolescents with past-month e-cigarette use, regardless of concurrent cannabis use, expressed interest in changing their use. However, only heaviness of e-cigarette use emerged as a predictor of intention to change suggesting. While fewer students expressed interest in changing their cannabis use, cannabis cravings and poly-tobacco use predicted intent to change. Overall, findings emphasize the need to tailor interventions towards adolescents engaging in more problematic substance use patterns.

### 1. Introduction

E-cigarette (electronic cigarette, including nicotine vaping) and cannabis use are prevalent among adolescents, with 5 and 7% of 8th, 10 and 12% of 10th, and 17 and 18% of 12th grade students using e-cigarettes and cannabis, respectively, in the past month in 2023 (Miech et al., 2024). Adolescents, especially 12th graders, who use e-cigarettes and cannabis are often doing so frequently; over one-third of all 12th graders who report past-30-day use of e-cigarettes and/or cannabis use daily (Miech et al., 2024). Regardless, many adolescents report a intention to quit. Data from the 2016–2018 Population Assessment of Tobacco and Health (PATH) study find almost half of adolescents who used e-cigarettes in the past month are thinking about quitting (Cuccia

et al., 2021; Smith et al., 2021). A national survey conducted in 2021 found that among adolescents and young adults who ever used e-cigarettes, 25% wanted to reduce their use and 35 % wanted to quit completely (Lin et al., 2024). Adolescents' intention to change cannabis use are less well understood. Similarly, intention to change use among those with co-use of e-cigarettes and cannabis need to be defined given prevalent concurrent use of both products in this demographic (Cohn et al., 2019; Liu et al., 2023, 2024; Schauer & Peters, 2018; Tucker et al., 2019).

Understanding characteristics associated with adolescent intention to quit or reduce e-cigarette use, cannabis use, and co-use are likely to help develop and direct effective supports to those with intention to change (Jenkins et al., 2017). Adolescents report engaging in e-cigarette

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and cannabis use, both sole use and co-use, as a method of coping with stress and other mental health issues (Davis et al., 2022; Kong et al., 2020), making quitting or reducing e-cigarette use more difficult (Das et al., 2016). School-related predictors, such as participation in school activities and academic grades, of intention to quit or reduce e-cigarette and cannabis use among adolescents must also be considered, as a majority of adolescents' social experiences as well as opportunities to receive substance use interventions take place in school settings (Huang et al., 2013; Liu et al., 2022; Peirson et al., 2016; Pulimeno et al., 2020). Previous studies have examined sociodemographic or behavioral predictors of intention to quit e-cigarette use, yet there is limited research on the impact of mental health and other substance use comorbidities (Cuccia et al., 2021; Smith et al., 2021). For intention to quit cannabis, research with adolescents has found that self-initiated or self-motivated cannabis cessation has been associated with lower levels of baseline cannabis use, "pro-drug" perceptions of harm, social motives, and self-efficacy (Dash & Anderson, 2015; Little et al., 2013). Research with young adults have found that more frequent use and previous quit attempts were associated with greater intention to quit cannabis use (Caviness et al., 2013), yet it is not known if these factors are associated with intention to quit cannabis use in adolescents. Regarding co-use of e-cigarettes and cannabis, research has focused on whether one substance influences the quitting of the other (among adults and young adults) (McClure et al., 2019; Vogel et al., 2018), but not factors associated with the quitting of both substances among adolescents.

Previous studies have looked at adolescents' intention to quit e-cigarette use (Cuccia et al., 2021; Smith et al., 2021), but did not look at intention to *reduce* use. Intention to reduce use, especially for cannabis, are less well understood and are relevant for informing harm reduction approaches (Jenkins et al., 2017). Harm reduction approaches meet adolescents where they are in the process of quitting or reducing substance use and promote a reduction of risk rather than an abstinence approach (Fischer, 2022). Harm reduction includes keeping oneself and others safer while they are using drugs, and is usually used for other drugs besides nicotine and cannabis (Fischer, 2022). For the context of our study, we refer to "harm reduction" as supporting students who may not be fully ready to quit, but have intention to reduce their e-cigarette or cannabis use.

This investigation aimed to describe the proportion of middle and high school students' intention to quit or reduce e-cigarette or cannabis use in the next 4 weeks, and identify sociodemographic, substance use, other mental health, and school-related factors that predict intention to quit or reduce use. Our goal was to improve our understanding of factors associated with intention to change e-cigarette and cannabis use in school-aged adolescents. This knowledge can help guide capacity building efforts around appropriate tiers of intervention development to optimally address student e-cigarette and cannabis use and their co-use. Our study is novel in that we look at adolescents' intention not only to quit e-cigarette use, cannabis use, and their co-use, but also intention to reduce use, to support a harm reduction perspective with adolescents.

## 2. Materials and methods

### 2.1. Participants

We administered a school-wide survey (Substance Use and Risk Factors Survey; SURF Survey) to students from 24 middle schools, 34 high schools, and 2 combined middle/high schools in Massachusetts in September 2022–February 2023 (PI: Schuster). Parents/guardians could opt their children out of the survey, and students were informed that the survey was confidential and voluntary. Procedures were approved by the Mass General Brigham Institutional Review Board.

### 2.2. Survey instrument and predictors

The SURF Survey covered a broad range of topics including

sociodemographic characteristics, substance use, mental health, physical health, and school experiences. Our samples of interest were determined based on separate queries as to whether students had used e-cigarettes and/or cannabis in the past 4 weeks. E-cigarettes were defined as "Vapes (for nicotine or flavors): Vapes include e-cigarettes, vape pens, e-cigars, e-hookahs, hookah pens, mods, and other electronic vapor products (e.g., Puff Bar, JUUL, SMOK, Sourin, Vuse and blu)." Cannabis was defined as Marijuana (e.g., pot, weed, cannabis THC, dab pens, edibles)."

We chose potential predictors based on a biopsychosocial model (Dodge & Pettit, 2003), which posits that adolescents' behaviors (such as e-cigarette and cannabis use) are a result of the interplay between biological predispositions, psychological factors (e.g., mental health), and sociocultural context (e.g., school experiences). We included sociodemographic characteristics such as: age, gender identity, race/ethnicity, sexual identity, and country of birthday. We examined substance use predictors including: past 4-week flavored nicotine product use, daily or near daily e-cigarette use, daily or near daily cannabis use, past 4-week other tobacco use (poly-tobacco use), timing of onset of nicotine cravings (within 60 min of waking, after 60 min of waking), and timing of onset of cannabis cravings (within 60 min of waking, after 60 min of waking). Psychological factors considered in the current investigation consisted of: scores from the depression/anxiety subscales of the Patient Health Questionnaire-4 (PHQ-4; range: 0–6,  $\geq 3$  "at-risk") (Kroenke et al., 2009), past year suicidal thoughts and behaviors (sum of 4 binary questions; range: 0–4), attention-deficit/hyperactivity disorder (ADHD; mean of 10 questions; range: 0–3), the Emotion Reactivity Scale (ERS; range: 0–84) (Nock et al., 2008), the Adolescent Psychotic-Like Symptom Screen (APSS; range: 0–7,  $\geq 2$  "at-risk") (Kelleher et al., 2011), and whether they had been prescribed a psychiatric medication in the past year (yes/no). Sociocultural predictors examined in the current investigation included school experiences: playing on school sports team in the past 12 months, academic grades, suspension within the past 12 months, suspension related to drugs/alcohol within the past 12 months, on-school campus substance use in the past 12-months, and having an individualized education program (IEP). Full details on the original survey and how response options were recoded as applicable for the current study are available in [Supplement 1](#). The survey was conducted via REDCap and offered in 17 languages.

### 2.3. Outcomes

We examined three different samples, including those with: (1) past 4-week e-cigarette use only and no past 4-week cannabis use (sole e-cigarette use), (2) past 4-week cannabis use only and no past 4-week e-cigarette use (sole cannabis use), and (3) past 4-week co-use of e-cigarettes and cannabis. We defined co-use of e-cigarettes and cannabis as use of both e-cigarettes and cannabis at any point in time in the past 4 weeks (including use on separate days, same-day use, and co-administration).

Outcomes were derived from questions on intention to change e-cigarette or cannabis use (queried separately) in the next 4 weeks, with response options of "No," "Yes, I'm planning to reduce (but not quit) use in the next 4 weeks," and "Yes, I'm planning to quit use completely in the next 4 weeks."

For sole e-cigarette use and sole cannabis use samples, we considered two outcomes: (1) intention to quit the given product vs. other response options (intention to reduce or no change), and (2) intention to reduce use of the given product weeks vs. other response options (intention to quit or no change). For the co-use sample, to avoid issues with low cell counts, we collapsed into a single intention to change category (intention to quit/reduce) and considered three outcomes: (1) intention to change for e-cigarettes vs. other response options (intention to change cannabis or no change), (2) intention to change for cannabis vs. other response options (intention to change e-cigarettes or no change), and (3) intention to change either or both products vs. no change for both

products. We therefore ran a total of seven analyses (2 for the sole e-cigarette use sample, 2 for the sole cannabis use sample, and 3 for the co-use sample).

### 2.4. Data analysis

The 2022–2023 SURF Survey included 33,252 records. We excluded 9,505 (28.6 %) survey records that failed to meet two quality control criteria, including removing records with less than 60 % overall completion and/or failure of two embedded attention checks. Missing data for the remaining records that met the quality control criteria (N = 23,747) were imputed via predictive mean matching with 10 iterations using the “mice” package in R (van Buuren & Groothuis-Oudshoorn, 2011).

We used chi-square tests to determine (a) whether frequencies for intention to quit, reduce, or no change differed among participants with sole e-cigarette use versus sole cannabis use and (b) among participants who co-used, whether frequencies for intention to change (quit/reduce) differed for e-cigarettes versus cannabis.

Predictors of intention to change outcomes were determined via a two-step process. First, we conducted an initial screen of potential predictors to exclude those that had little to no predictive utility for subsequent analyses using a variant of the least absolute shrinkage and selection operator (LASSO), specifically a stacked LASSO logistic regression model implemented in the “miselect” package in R (Du et al., 2022). The LASSO imposes a penalty term that shrinks regression coefficients to zero, and coefficients for weak predictors get reduced completely to zero. The magnitude of the penalty term is determined via cross-validation, selecting a penalty that produces the best out-of-sample predictive performance. Second, any predictors that “survived” the stacked LASSO with non-zero coefficients were then included in a multilevel logistic regression with a school-varying intercept to identify which variables were statistically significant predictors of a given outcome while appropriately controlling for clustered data. P-values were corrected for multiple comparisons using the Benjamini-Hotchberg method, separately by outcome.

## 3. Results

### 3.1. Prevalence of e-cigarette use, cannabis use, and co-use

A total of 1905 (8.0 %) of students reported using either e-cigarettes or cannabis in the past 4 weeks: 543 (2.3 %) with sole e-cigarette use, 546 (2.3 %) with sole cannabis use, and 816 (3.4 %) with co-use. See Table 1 and Supplement 2 for participant characteristics by past 4-week sole e-cigarette use, sole cannabis use, and co-use, as well as lack of use of either e-cigarettes or cannabis in the past 4 weeks. Among high school students (n = 16,011), a total of 1698 (10.6 %) of reported using either e-cigarettes or cannabis: 425 (2.7 %) with sole e-cigarette use, 524 (3.3 %) with sole cannabis use, and 749 (4.7 %) with co-use.

### 3.2. Prevalence of intention to quit, reduce, or change use among analytic samples

Participants with sole e-cigarette use were more likely to report wanting to change their use in the next 4 weeks compared to those with sole cannabis use ( $X^2(2) = 144.1, p < 0.001$ ). Only a minority of participants with sole e-cigarette use reported no intention to change use in the next 4 weeks 190 (35.0%); 222 (40.9%) intended to quit and 131 (24.1%) intended to reduce use in the next 4 weeks. In contrast, among participants with sole cannabis use, a majority (n = 351, 64.3 %) reported no intention to change use in the next 4 weeks, with 58 (10.6%) reporting an intention to quit and 137 (25.1%) reporting an intention to reduce.

Intention to change e-cigarette use was also higher than intention to change cannabis use among those with past 4-week co-use of both

**Table 1**

Demographics of Three Analytic Samples (Sole E-Cigarette Use Sole Cannabis Use, Co-Use) and Participants without Past 4-Week E-Cigarette or Cannabis Use.

	Sole E-Cigarette Use in Past 4 Weeks (n = 543)	Sole Cannabis Use in Past 4 Weeks (n = 546)	Co-use of E-Cigarettes and Cannabis in Past 4 weeks (n = 816)	No Past 4-Week E-Cigarette or Cannabis Use (n = 21,842)
Age (mean, sd)	15.5 (1.8)	16.5 (1.3)	16.2 (1.5)	14.6 (1.9)
Gender identity				
<i>Cis-gender</i>	512 (94.3 %)	487 (89.2 %)	724 (88.7 %)	20,445 (93.6 %)
<i>Gender diverse/ Not sure</i>	26 (4.8 %)	50 (9.2 %)	81 (9.9 %)	1095 (5.0 %)
<i>Missing</i>	5 (0.9 %)	9 (1.6 %)	11 (1.3 %)	301 (1.4 %)
Race/ethnicity				
<i>Non-Hispanic White</i>	317 (58.4 %)	382 (70.0 %)	507 (62.1 %)	12,990 (59.5 %)
<i>Non-Hispanic Black</i>	20 (3.7 %)	12 (2.2 %)	29 (3.6 %)	884 (4.0 %)
<i>Hispanic/Latino</i>	124 (22.8 %)	65 (11.9 %)	152 (18.6 %)	3940 (18.0 %)
<i>Multiple</i>	45 (8.3 %)	59 (10.8 %)	93 (11.4 %)	1766 (8.1 %)
<i>Other</i>	27 (5.0 %)	21 (3.8 %)	22 (2.7 %)	1938 (8.5 %)
<i>Missing</i>	10 (1.8 %)	7 (1.3 %)	13 (1.6 %)	324 (1.5 %)
Sexual identity				
<i>Heterosexual</i>	383 (70.5 %)	345 (63.2 %)	515 (63.1 %)	16,335 (74.8 %)
<i>Bisexual</i>	91 (16.8 %)	77 (14.1 %)	145 (17.7 %)	1596 (7.3 %)
<i>Gay/Lesbian</i>	21 (3.9 %)	32 (5.9 %)	33 (4.0 %)	570 (2.6 %)
<i>Other (Asexual, Pansexual, Queer, Questioning, Something else)</i>	33 (6.1 %)	182 (15.0 %)	105 (12.9 %)	1911 (8.7 %)
<i>Missing</i>	15 (2.8 %)	10 (1.8 %)	105 (12.9 %)	1430 (6.5 %)
Country of birth				
<i>Not US</i>	65 (12.0 %)	36 (6.6 %)	56 (6.9 %)	2361 (10.8 %)
<i>US</i>	476 (87.7 %)	507 (92.9 %)	757 (92.8 %)	19,342 (88.6 %)
<i>Missing</i>	2 (0.4 %)	3 (0.5 %)	3 (0.4 %)	139 (0.6 %)

Note. Numbers presented represent n (%) unless otherwise noted.

substances ( $X^2(1) = 62.1, p < 0.001$ ). Among participants who co-used e-cigarettes and cannabis, 322 (39.5%), reported no intention to change in the next 4 weeks, followed by 224 (27.5%) with intention to quit or reduce (quit/reduce) e-cigarettes only, 214 (26.2%) with intention to quit/reduce both substances, and 55 (6.9%) with intention to quit/reduce cannabis only. Therefore, among participants who co-used, 438 (53.7%) had intention to quit/reduce at least e-cigarette use compared to 279 (34.2%) who had intention to quit/reduce at least cannabis use (Supplement 3).

### 3.3. Predictors for intention to change use among analytic samples

Among participants with sole e-cigarette use, less than daily or near daily e-cigarette use predicted intention to quit (OR = 1.56,  $p < 0.01$ ) as well as intention to reduce (OR = 1.67,  $p < 0.01$ ). See Table 2 for results on all included predictors. There were no significant predictors identified for intention to quit cannabis use among those with sole past 4-week cannabis use ( $p$ 's > 0.42). Later onset of craving for cannabis after waking (i.e., after 60 min of waking) predicted increased odds of

**Table 2**  
Adjusted Regression Results of Logistic Mixed Effects Models for Intention to Quit and Reduce E-Cigarette Use in the Next 4 Weeks among Participants with Sole E-Cigarette Use in the Past 4-Weeks (N = 543).

	Intention to Quit (vs. Intention to Reduce and No Intention to Quit/Reduce) <sup>a</sup>			Intention to Reduce (vs. Intention to Quit and No intention to Quit/Reduce) <sup>b</sup>		
	aOR	95 % CI	p-value <sup>c</sup>	aOR	95 % CI	p-value <sup>c</sup>
<b>Demographics</b>						
Age	0.79	0.63–0.97	0.08			
Gender identity <i>Cis-gender (ref)</i> <i>Not cis-gender</i>						
Race/ethnicity <i>Non-Hispanic White (ref)</i> <i>Non-Hispanic Black</i> <i>Hispanic/Latino</i> <i>Multiple</i> <i>Other</i>						
Sexual identity <i>Heterosexual (ref)</i> <i>Bisexual</i> <i>Gay/Lesbian</i> <i>Other (Asexual, Pansexual, Queer, Questioning, Something else)</i>	1.48	1.03–2.12	0.08			
	0.79	0.51–1.22	0.34			
	0.78	0.52–1.15	0.30			
Country of birth <i>US born (ref)</i> <i>Not US born</i>	0.91	0.75–1.10	0.34	0.87	0.72–1.05	0.32
<b>Substance Use</b>						
Past 4-week flavored nicotine product use <i>Not sure/Tobacco (ref)</i> <i>Fruit/Spice/Mint</i>	0.64	0.52–0.79	<0.01	0.60	0.49–0.74	<0.01
Daily or near daily e-cigarette use (4–7 days/week)						
Past 4-week other tobacco use (not including e-cigarettes) Craving Nicotine <i>More than 60 min of waking (ref)</i> <i>Within 60 min of waking</i>						
Mental Health Anxiety or depression (PHQ-4; <sup>1</sup> range: 0–12, ≥3 “at-risk”)				0.95	0.78–1.16	0.78
Suicidal thoughts and behaviors in past 12				0.97	0.79–1.19	0.84

**Table 2 (continued)**

	Intention to Quit (vs. Intention to Reduce and No Intention to Quit/Reduce) <sup>a</sup>			Intention to Reduce (vs. Intention to Quit and No intention to Quit/Reduce) <sup>b</sup>		
	aOR	95 % CI	p-value <sup>c</sup>	aOR	95 % CI	p-value <sup>c</sup>
months (range 0–4)						
ADHD symptoms (range 0–3)						
Emotional reactivity (ERS; <sup>2</sup> range 0–84) (mean, SD)						
Psychotic-like symptoms (APSS; <sup>3</sup> range 0–7) (mean, SD)						
Psychiatric medication						
<b>Physical Health</b>						
Days of physical activity in last 7 days (range 0–7 days)						
<b>School Experiences</b>						
Sports team	0.85	0.69–1.04	0.23	0.87	0.71–1.06	0.32
Academic grades <i>Mostly A's/B's (ref)</i> <i>Mostly C's</i> <i>Mostly D/F's</i> <i>Mixed</i>	1.24	0.87–1.77	0.30	1.32	0.93–1.88	0.32
	0.78	0.53–1.15	0.30	0.80	0.55–1.17	0.43
	1.15	0.83–1.61	0.40	1.14	0.82–1.58	0.61
Suspension within past 12 months				1.02	0.84–1.24	0.84
Suspension related to drugs/alcohol within past 12 months						
On-school campus substance use in past 12 months	0.80	0.66–0.96	0.08			
IEP						

Note: (a) Gender, race/ethnicity, sexual orientation, past 4-week flavored nicotine produce use, e-cigarette dependence, past 4-week other tobacco use, anxiety or depression, suicidal thoughts and behaviors in the past 12-months, ADHD symptoms, taking psychiatric medication, adolescent psychotic-like symptoms, emotional reactivity, physical activity, suspension within the past 12-months, suspension related to drugs/alcohol within the past 12-months, and IEP were not included in the adjusted model for intention to quit e-cigarette use, as they had a zero-valued point estimate based on the stacked LASSO. (b) Age, gender, race/ethnicity, sexual orientation, past 4-week flavored nicotine produce use, e-cigarette dependence, past 4-week other tobacco use, ADHD symptoms, taking psychiatric medication, adolescent psychotic-like symptoms, emotional reactivity, physical activity, suspension related to drugs/alcohol within the past 12-months, use of drugs at school in the past 12-months, and IEP were not included in the adjusted model for intention to reduce e-cigarette use, as they had a zero-valued point estimate based on the stacked LASSO. (c) Significance was determined at alpha = 0.05, and p-values were corrected for multiple comparisons using the Benjamini-Hotchberg method.

<sup>1</sup> Anxiety or depression was screened using the PHQ-4 (Kroenke, K., Spitzer, R. L., Williams, J. B., & Löwe, B. (2009). An ultra-brief screening scale for anxiety

and depression: the PHQ-4. *Psychosomatics*, 50(6), 613–621. <https://doi.org/10.1176/appi.psy.50.6.613>. Scores are rated as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). Having a total score of  $\geq 3$  for first two question screens for anxiety, and a total score of  $\geq 3$  for the last two questions screens for depression.

<sup>2</sup> Emotional reactivity was screened using the emotional reactivity scale (Nock MK, Wedig MM, Holmberg EB, Hooley JM. The emotion reactivity scale: development, evaluation, and relation to self-injurious thoughts and behaviors. *Behav Ther.* 2008 Jun;39(2):107–16. <https://doi.org/10.1016/j.beth.2007.05.005>. Epub 2007 Oct 29. PMID: 18502244).

<sup>3</sup> Having psychotic-like experiences was screened using the Adolescent Psychotic-Like Symptom Screener (APSS) (Kelleher, I., Harley, M., Murtagh, A., & Cannon, M. (2011). Are screening instruments valid for psychotic-like experiences? A validation study of screening questions for psychotic-like experiences using in-depth clinical interview. *Schizophrenia bulletin*, 37(2), 362–369. <https://doi.org/10.1093/schbul/sbp057>).

intention to reduce use among participants with sole cannabis use (OR = 1.82,  $p < 0.01$ ). See Table 3 for results on all included predictors.

No significant predictors emerged for intention to quit/reduce e-cigarettes among those with past 4-week co-use of e-cigarettes and cannabis ( $p$ 's  $> 0.09$ ). There were several predictors for intention to quit/reduce cannabis use among those with e-cigarette and cannabis co-use: younger age (OR = 1.22,  $p = 0.03$ ), non-flavored e-cigarette use (OR = 1.18,  $p = 0.04$ ), non-polytobacco use (OR = 1.28,  $p = 0.01$ ), and later onset of craving for cannabis after waking (i.e., after 60 min of waking) (OR = 1.37,  $p < 0.01$ ). Non-polytobacco use was the single identified predictor of greater intention to quit/reduce e-cigarettes and/or cannabis (vs. no intended change for both substances) among those with co-use (OR = 1.25,  $p = 0.03$ ). See Table 4 for results on all included predictors across outcomes.

#### 4. Discussion

Our findings indicate that most adolescents using e-cigarettes and/or cannabis engage in co-use, followed by roughly equal percentages who engage in sole use of either e-cigarettes or cannabis. Intention to quit or reduce e-cigarette use was consistently more common than for cannabis use across participants who only vaped nicotine as well as those with concomitant e-cigarette and cannabis use. Roughly two-thirds of participants with sole use of e-cigarettes and half of participants with co-use expressed intention to quit or reduce use compared to only one-third of participants who wanted to change their cannabis use behavior. Among participants who had used e-cigarettes in the past 4-weeks, we found a lower prevalence of wanting to quit e-cigarette use compared to previous PATH studies (Cuccia et al., 2021; Smith et al., 2021). This may be because those studies were conducted when e-cigarettes were just becoming popular among adolescents and habits may have been less entrenched (Glantz et al., 2022).

Co-use of e-cigarettes and cannabis in the past 4-weeks was prevalent in our sample, with over half of participants with current e-cigarette or cannabis use also reporting co-use of the other substance. This supports existing findings from 2019 Massachusetts Youth Health Survey data showing that co-use of e-cigarettes and cannabis was more prevalent among adolescents than sole use of either substance alone (Liu et al., 2023). Co-use of any tobacco/nicotine product and cannabis among adolescents is associated with higher risk of addiction, along with worse physical and mental health outcomes (Berg et al., 2021; Cuccia et al., 2021; Dai, 2021; Masters et al., 2018; Nguyen et al., 2019; Ramo et al., 2012; Tucker et al., 2019).

We also examined factors predicting intention to change e-cigarette/cannabis use. Despite a conservative 2-step approach in which predictors had to both demonstrate out-of-sample predictive utility and statistical significance, several factors (younger age, less than daily or near daily e-cigarette use, denying flavored e-cigarette use, non-polytobacco use, and later onset of craving for cannabis after waking) emerged as notable predictors for intention to quit, reduce, or overall

**Table 3**

Adjusted Regression Results of Logistic Mixed Effects Models for Intention to Quit and Reduce Cannabis Use in the Next 4 Weeks among Participants with Sole Cannabis Use in the Past 4-Weeks (N = 546).

	Intention to Quit (vs. Intention to Reduce and No intention to Quit/Reduce) <sup>a</sup>			Intention to Reduce (vs. Intention to Quit and No intention to Quit/Reduce) <sup>b</sup>		
	aOR	95 % CI	p-value <sup>c</sup>	aOR	95 % CI	p-value <sup>c</sup>
<b>Demographics</b>						
Age				0.91	0.73–1.13	0.48
Gender Identity						
<i>Cis-gender (ref)</i>						
<i>Not cis-gender</i>						
Race/ethnicity						
<i>Non-Hispanic White (ref)</i>						
<i>Non-Hispanic Black</i>	1.13	0.57–2.25	0.75	1.67	0.94–2.99	0.17
<i>Hispanic/Latino</i>	0.83	0.47–1.49	0.74	1.12	0.72–1.72	0.73
<i>Multiple</i>	0.85	0.35–2.06	0.75	1.14	0.62–2.09	0.75
<i>Other</i>	1.52	0.79–2.91	0.42	0.62	0.28–1.36	0.32
Sexual Identity						
<i>Heterosexual (ref)</i>						
<i>Bisexual</i>						
<i>Gay/Lesbian</i>						
<i>Other (Asexual, Pansexual, Queer, Questioning, Something else)</i>						
Country of birth						
<i>US born (ref)</i>						
<i>Not US born</i>	0.96	0.73–1.25	0.75	1.01	0.81–1.26	0.95
Substance Use						
Daily or Near Daily Cannabis use (4–7 days/week)	0.74	0.51–1.06	0.42	1.34	1.08–1.67	0.05
Past 4-week other tobacco use (not including e-cigarettes)						
Craving Cannabis						
<i>More than 60 min of waking (ref)</i>						
<i>Within 60 min of waking</i>				0.55	0.40–0.77	<0.01
Mental Health						
Anxiety or depression (PHQ-4; <sup>1</sup> range: 0–12, $\geq 3$ “at-risk”)	1.20	0.89–1.60	0.42	0.82	0.64–1.06	0.21
Suicidal thoughts and behaviors in past 12 months (range 0–4)				0.73	0.57–0.94	0.07
ADHD symptoms (range 0–3)	1.21	0.90–1.61	0.42	1.20	0.95–1.53	0.21
Emotional reactivity						

(continued on next page)

Table 3 (continued)

	Intention to Quit (vs. Intention to Reduce and No intention to Quit/Reduce) <sup>a</sup>			Intention to Reduce (vs. Intention to Quit and No intention to Quit/Reduce) <sup>b</sup>		
	aOR	95 % CI	p-value <sup>c</sup>	aOR	95 % CI	p-value <sup>c</sup>
(ERS; <sup>2</sup> range 0–84)						
Psychotic-like symptoms (APSS; <sup>3</sup> range 0–7)				1.29	1.03–1.63	0.08
Psychiatric medication				0.86	0.68–1.08	0.30
<b>Physical Health</b>						
Days of physical activity in last 7 days (range 0–7 days)						
<b>School-related Experiences</b>						
Sports team						
Academic grades						
Mostly A's/B's (ref)						
Mostly C's				0.66	0.42–1.05	0.17
Mostly D/F's				1.04	0.64–1.69	0.93
Mixed				1.60	1.07–2.37	0.07
Suspension within the past 12-months				1.26	1.02–1.56	0.08
Suspension related to drugs/alcohol within the past 12-months	0.71	0.38–1.32	0.45			
On-school campus substance use in past 12 months	0.80	0.58–1.11	0.42			
IEP						

Note: (a) Age, gender, sexual identity, country of birth, past 4-week other tobacco use, cannabis dependence, suicidal thoughts and behaviors in the past 12-months, adolescent psychotic-like symptoms, emotional reactivity, taking psychiatric medication, physical activity, school sports, academic grades, suspension within the past 12-months, and IEP were not included in the adjusted model for intention to quit cannabis use, as they had a zero-valued point estimate based on the stacked LASSO. (b) Gender, sexual identity, country of birth, past 4-week other tobacco use, emotional reactivity, physical activity, school sports, suspension related to drugs/alcohol within the past 12-months, use of drugs at school in the past 12-months, and IEP were not included in the adjusted model for intention to reduce cannabis use, as they had a zero-valued point estimate based on the stacked LASSO. (c) Significance was determined at alpha = 0.05, and p-values were corrected for multiple comparisons using the Benjamini-Hotchberg method.

<sup>1</sup> Anxiety or depression was screened using the PHQ-4 (Kroenke, K., Spitzer, R. L., Williams, J. B., & Löwe, B. (2009). An ultra-brief screening scale for anxiety and depression: the PHQ-4. *Psychosomatics*, 50(6), 613–621. <https://doi.org/10.1176/appi.psy.50.6.613>). Scores are rated as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). Having a total score of ≥ 3 for first two question screens for anxiety, and a total score of ≥ 3 for the last two questions screens for depression.

<sup>2</sup> Emotional reactivity was screened using the emotional reactivity scale (Nock MK, Wedig MM, Holmberg EB, Hooley JM. The emotion reactivity scale: development, evaluation, and relation to self-injurious thoughts and behaviors. *Behav Ther.* 2008 Jun;39(2):107–16. <https://doi.org/10.1016/j.beth.2007.05.005>. Epub 2007 Oct 29. PMID: 18502244).

<sup>3</sup> Having psychotic-like experiences was screened using the Adolescent Psychotic-Like Symptom Screener (APSS) (Kelleher, I., Harley, M., Murtagh, A., & Cannon, M. (2011). Are screening instruments valid for psychotic-like

experiences? A validation study of screening questions for psychotic-like experiences using in-depth clinical interview. *Schizophrenia bulletin*, 37(2), 362–369. <https://doi.org/10.1093/schbul/sbp057>.

intention to change. However, predictors of intention to change were not consistent across intention type (quit vs. reduce) or sole use versus co-use. For example, we found a larger number of predictors for intention to change cannabis use among participants who co-used (younger age, denying flavored e-cigarette use, non-polytobacco use, later onset of craving for cannabis after waking), yet we observed only one predictor for intention to change co-use (non-polytobacco use) and no predictors for intention to change e-cigarette use. As for sole use, less than daily or near daily e-cigarette use reliably predicted both intention to quit and intention to reduce. Yet for sole cannabis use, we found that later onset of craving for cannabis after waking only predicted intention to reduce, not intention to quit.

Our results suggest that practitioners should avoid a “one size fits all” approach when designing strategies and supporting adolescents with intention to quit or reduce e-cigarettes, cannabis, and their co-use. Practitioners will need to take in account (a) higher intention to change e-cigarette use (vs. cannabis), (b) preference towards intention to reduce rather than quit for people with sole cannabis or co-use of e-cigarettes/cannabis, (c) the impact of dependence indicators on intention to change, and (d) the impact of poly-tobacco use on intention to change among participants who co-used.

The lower prevalence of intention to quit or reduce cannabis is likely driven by perceptions that cannabis is less harmful, has less associated stigma, and is likely less addictive compared to tobacco/e-cigarettes (Davis et al., 2022; Lozano et al., 2020; Zehra et al., 2018). Adolescents tend to have a lower harm perception of cannabis (vs. e-cigarettes) (Chambers et al., 2023; Nguyen et al., 2023). Practitioners therefore may want to consider educating adolescents to better perceive the harms of cannabis, and thus align adolescent attitudes towards cannabis to be closer to existing adolescent attitudes towards e-cigarette use (Chambers et al., 2023; Nguyen et al., 2023). This alignment of harm perceptions between both substances may help encourage intention to change for adolescents who use cannabis and open the door for broader interventions that can be applied to both substances and their co-use (Davis et al., 2022; Lozano et al., 2020; Zehra et al., 2018).

For sole cannabis use, the proportion of participants reporting an intention to reduce use was higher than intention to quit. Interventions should consider addressing harm reduction in addition to abstinence to engage a broader proportion of adolescents in care. Harm reduction approaches meet adolescents where they are in the quitting process and promote a reduction of the dangers and risk of substance use (Fischer, 2022). Such school-based harm reduction programs are appealing to adolescents, often more effective in longer-term engagement in care, associated with improved functional outcomes, and increasing the likelihood of subsequent reductions or quitting (Fischer, 2022; Leslie, 2008). Previous studies had only looked at adolescents’ intention to quit, and future research should continue to include intention to reduce use as an outcome given the wider acceptability of harm reduction approaches by adolescents.

Dependence indicators emerged as predictors for intention to change. Less than daily or near daily use of e-cigarettes predicted intention to quit and reduce among those with sole e-cigarette use. Later onset of craving for cannabis after waking predicted intention to reduce cannabis among those with sole cannabis use and intention to change among those who co-used. Early morning cannabis cravings may be an indicator for cannabis dependence (Lee et al., 2014), and withdrawal may make behavior change more challenging (Lee et al., 2014), especially among adolescents who are self-initiating cannabis cessation (Sullivan et al., 2022). Adolescents with cannabis dependence may experience withdrawal symptoms in between periods of use (Bonnet & Preuss, 2017; Morean et al., 2018; Vogel et al., 2019), and may also have more continual access to products (Kong et al., 2021), making quitting

**Table 4**

Adjusted Regression Results of Logistic Mixed Effects Models for Intention to Quit/Reduce E-Cigarettes Only, Quit/Reduce Cannabis Only, and Quit/Reduce Either E-Cigarettes and/or Cannabis in the Next 4 Weeks among Participants who Co-used Cannabis and E-Cigarettes in the Past 4-Weeks (N = 816).

	Intention to Quit/Reduce E-Cigarettes (vs. Intention to Quit/Reduce Cannabis Only and No Intention to Quit/Reduce Both) <sup>a</sup>			Intention to Quit/Reduce Cannabis (vs. Intention to Quit/Reduce E-Cigarettes Only and No Intention to Quit/Reduce Both) <sup>b</sup>			Intention to Quit/Reduce Either E-Cigarettes and/or Cannabis (vs. No Intention to Quit/Reduce Both) <sup>c</sup>		
	aOR	95 % CI	p-value <sup>d</sup>	aOR	95 % CI	p-value <sup>d</sup>	aOR	95 % CI	p-value <sup>d</sup>
<b>Demographics</b>									
Age				<b>0.82</b>	<b>0.70–0.97</b>	<b>0.03</b>			
Gender Identity									
<i>Cis-gender (ref)</i>									
<i>Not cis-gender</i>									
Race/ethnicity									
<i>Non-Hispanic White (ref)</i>									
<i>Non-Hispanic Black</i>									
<i>Hispanic/Latino</i>									
<i>Multiple</i>									
<i>Other</i>									
Sexual Identity									
<i>Heterosexual (ref)</i>									
<i>Bisexual</i>	0.93	0.72–1.21	0.70				1.01	0.78–1.31	0.98
<i>Gay/Lesbian</i>	0.83	0.60–1.13	0.44				0.86	0.63–1.18	0.72
<i>Other (Asexual, Pansexual, Queer, Questioning, Something else)</i>	1.11	0.84–1.46	0.61				0.98	0.75–1.29	0.98
Country of birth									
<i>US born (ref)</i>									
<i>Not US born</i>	1.15	0.99–1.34	0.22				1.11	0.95–1.29	0.41
<b>Substance Use</b>									
Past 4-week flavored nicotine product use									
<i>Not sure/Tobacco (ref)</i>									
<i>Fruit/Spice/Mint</i>				<b>0.85</b>	<b>0.74–0.98</b>	<b>0.04</b>			
Daily or near daily e-cigarette use (4–7 days/week)	0.88	0.74–1.05	0.34						
Daily or near daily cannabis use (4–7 days/week)				0.95	0.79–1.13	0.53			
Past 4-week other tobacco use (not including e-cigarettes)	0.87	0.75–1.02	0.22	<b>0.78</b>	<b>0.66–0.92</b>	<b>0.01</b>	<b>0.80</b>	<b>0.68–0.93</b>	<b>0.03</b>
Craving Nicotine									
<i>More than 60 min of waking (ref)</i>									
<i>Within 60 min of waking</i>	0.92	0.77–1.11	0.56				0.96	0.81–1.13	0.98
Craving Cannabis									
<i>More than 60 min of waking (ref)</i>									
<i>Within 60 min of waking</i>	0.79	0.67–0.93	0.09	<b>0.73</b>	<b>0.69–0.89</b>	<b>0.01</b>	0.81	0.68–0.97	0.10
<b>Mental Health</b>									
Anxiety or depression (PHQ-4; <sup>1</sup> range: 0–12, ≥3 “at-risk”)									
Suicidal thoughts and behaviors in the past 12 months (range 0–4)									
ADHD symptoms (range 0–3)									
Emotional reactivity (ERS; <sup>2</sup> range 0–84)									
Psychotic-like symptoms (APSS; <sup>3</sup> range 0–7)							0.87	0.82–1.15	0.98
Psychiatric medication	0.92	0.79–1.11	0.48						
<b>Physical Health</b>									
Days of physical activity in last 7 days (range 0–7 days) (mean, SD)									
<b>School-related Experiences</b>									
Sports team									
Academic grades									
<i>Mostly A's/B's (ref)</i>									
<i>Mostly C's</i>	0.93	0.72–1.21	0.70				1.00	0.77–1.30	1.00
<i>Mostly D/F's</i>	0.78	0.58–1.05	0.24				0.79	0.59–1.05	0.28
<i>Mixed</i>	1.25	0.98–1.60	0.22				1.27	0.99–1.63	0.19
Suspension within the past 12-months	0.97	0.78–1.200	0.77				0.95	0.77–1.18	0.98
Suspension related to drugs/alcohol within the past 12-months	0.96	0.77–1.19	0.76				0.98	0.79–1.22	0.98
On-school campus substance use in past 12 months	0.94	0.81–1.09	0.56	0.90	0.77–1.05	0.20	0.86	0.74–1.00	0.18
IEP	1.21	1.03–1.41	0.13						

Note: (b) Gender, race/ethnicity, sexual identity, country of birth, daily or near daily e-cigarette use, cannabis dependence, anxiety or depression, suicidal thoughts and behaviors in the past 12-months, adolescent psychotic-like symptoms, ADHD symptoms, emotional reactivity, taking psychiatric medication, physical activity, school sports, academic grades, suspension within the past 12-months, suspension related to drugs/alcohol within the past 12-months, and IEP were not included in the adjusted model for intention to quit/reduce cannabis only, as they had a zero-valued point estimate based on the stacked LASSO. (c) Gender, race/ethnicity, past 4-week flavored nicotine produce use, daily or near daily e-cigarette use, anxiety or depression, suicidal thoughts and behaviors in the past 12-months, ADHD symptoms, emotional reactivity, taking psychiatric medication, physical activity, school sports, and IEP were not included in the adjusted model for intention to quit/reduce either e-cigarettes and/or cannabis, as they had a zero-valued point estimate based on the stacked LASSO. (a) Age, gender, race/ethnicity, past 4-week flavored nicotine produce use, daily or near daily cannabis use, anxiety or depression, suicidal thoughts and behaviors in the past 12-months, ADHD symptoms, adolescent psychotic-like symptoms, emotional reactivity, physical activity, and school sports were not included in the adjusted model for intention to quit/reduce e-cigarettes only, as they had a zero-valued point estimate based on the stacked LASSO. (d) Significance was determined at  $\alpha = 0.05$ , and p-values were corrected for multiple comparisons using the Benjamini-Hochberg method.

<sup>1</sup> Anxiety or depression was screened using the PHQ-4 (Kroenke, K., Spitzer, R. L., Williams, J. B., & Löwe, B. (2009). An ultra-brief screening scale for anxiety and depression: the PHQ-4. *Psychosomatics*, 50(6), 613–621. <https://doi.org/10.1176/appi.psy.50.6.613>). Scores are rated as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). Having a total score of  $\geq 3$  for first two question screens for anxiety, and a total score of  $\geq 3$  for the last two questions screens for depression.

<sup>2</sup> Emotional reactivity was screened using the emotional reactivity scale (Nock MK, Wedig MM, Holmberg EB, Hooley JM. The emotion reactivity scale: development, evaluation, and relation to self-injurious thoughts and behaviors. *Behav Ther*. 2008 Jun;39(2):107–16. <https://doi.org/10.1016/j.beth.2007.05.005>. Epub 2007 Oct 29. PMID: 18502244).

<sup>3</sup> Having psychotic-like experiences was screened using the Adolescent Psychotic-Like Symptom Screener (APSS) (Kelleher, I., Harley, M., Murtagh, A., & Cannon, M. (2011). Are screening instruments valid for psychotic-like experiences? A validation study of screening questions for psychotic-like experiences using in-depth clinical interview. *Schizophrenia bulletin*, 37(2), 362–369. <https://doi.org/10.1093/schbul/sbp057>).

or reducing use more difficult. Moreover, one study among adolescents found that reporting cannabis withdrawal was moderated by problem recognition (Greene & Kelly, 2014). Interventions aimed at increasing intention to change should include psychoeducational material on the expected intensity and time course for withdrawal and teach coping strategies to assist during this period of temporary discomfort (Budney et al., 2004). Additionally, future research is needed to determine whether engaging in cessation interventions when offered vary by dependence.

Among participants who co-used, we found that non-polytobacco use was associated with intention to change both e-cigarette and cannabis use, and cannabis use only, but not for intention to change e-cigarettes use only. Findings implicate the potential value in addressing both tobacco (including e-cigarettes) and cannabis together, as well as the ways in which one may reinforce the other, in prevention and treatment efforts (Berg et al., 2021). Substance use prevention efforts should continue to educate adolescents around the harms of co-use and poly-substance use of different types of tobacco and cannabis products, versus sole-use.

Our study has limitations. We surveyed schools in Massachusetts and findings may not generalize to students in other states. Rates of past 4-week e-cigarette and cannabis use were also lower than national estimates (National Institute on Drug Abuse, 2021), which may be due to self-report bias or systematic bias of those with e-cigarette or cannabis use to complete the survey. Another possible explanation for why the rates of e-cigarette, cannabis, and co-use were low in our sample is because we included participants in middle school (not just high school). Yet, it is important to include middle-school-aged participants, as e-cigarette and cannabis use initiation is occurring at such earlier ages (Staff et al., 2022; Sun et al., 2022). Due to survey limitations, our study could not distinguish between types of co-use (e.g., same day, co-administration), and future surveys should utilize more detailed measures that ask about e-cigarette and cannabis use within the same question. Finally, our study looked at intention to quit and reduce e-cigarette and cannabis use, not actual changes in use. Future studies should continue to assess what factors related to sociodemographic characteristics, substance use, mental health, physical health, and school experiences predict quitting/reducing e-cigarette and cannabis use.

Findings highlight that there is a large proportion of adolescents who want to quit or reduce their use of e-cigarettes and/or cannabis. Adolescents may be receptive to treatment and interventions (Noar et al., 2019), underscoring the need to make resources easily accessible, such as school-based diversion programs for students with intention to change e-cigarette, cannabis, and/or their co-use (Liu et al., 2023). This study highlights the need to develop evidence-based programs,

especially focused on co-use of tobacco and cannabis, that can be made broadly available to better support those adolescents with intention to quit or reduce use. Overall, findings support the need to tailor such programs towards adolescents engaging in problematic substance use patterns. Future research should also define barriers and facilitators of adolescents' access and participation in such programs and continue to evaluate the efficacy of harm reduction approaches.

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#### CRediT authorship contribution statement

**Jessica Liu:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Sarah J. Knoll:** Writing – review & editing, Project administration, Data curation. **Michael P. Pascale:** Writing – review & editing, Project administration, Methodology, Data curation. **Caroline A. Gray:** Writing – review & editing, Project administration. **Alec Bodolay:** Writing – review & editing, Project administration, Methodology, Data curation. **Kevin W. Potter:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization. **Jodi Gilman:** Writing – review & editing. **A. Eden Evins:** Writing – review & editing. **Randi M. Schuster:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.



## Data availability

Data will be made available on request.

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## Appendix A. Supplementary material

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