HHS Public Access

Author manuscript

Drug Alcohol Depend. Author manuscript; available in PMC 2021 November 01.

Published in final edited form as:

Drug Alcohol Depend. 2020 November 01; 216: 108258. doi:10.1016/j.drugalcdep.2020.108258.

Young adult e-cigarette use: A latent class analysis of device and flavor use, 2018-2019

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Abstract

Objective: The myriad of e-cigarette devices and flavors used by young adults (YAs) complicates identification of the particular e-cigarette products that are associated with more frequent tobacco use and merit consideration for regulation. The current study used latent class analysis to identify distinct patterns of e-cigarette device and flavor use and evaluate their association with vaping and smoking frequency.

Methods: Cross-sectional survey data (2018–2019) from a Southern California cohort were analyzed. YAs reporting past 30-day nicotine vaping (N = 550; M age = 19.2 years) self-reported e-cigarette device type/brand and flavor. Six device (e-cig/vape pen, mech mod, box mod, JUUL, non-JUUL pod, disposable) and three flavor (tobacco, mint/menthol, sweet/fruit) indicators were included in a latent class analysis. Past 30-day nicotine vaping and cigarette smoking frequency were assessed as correlates of device and flavor class membership.

Results: Three classes were identified: Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users (prevalance:47%); Non-JUUL–Sweet/Fruit Flavor Users (28%); and Poly-Device–Poly-Flavor Users (25%). Greater frequency of vaping and smoking were associated with higher odds of belonging to the Poly-Device–Poly-Flavor Users class vs. the Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users (vaping: aOR[95%CI] = 1.36[1.16, 1.59], p < .001; smoking: aOR[95%CI] = 1.25[1.02, 1.54], p = .03) and Non-JUUL–Sweet/Fruit Flavor Users (vaping: aOR [95%CI] = 1.30[1.10, 1.53], p < .01; smoking: aOR[95%CI] = 1.42[1.07, 1.88], p = .02) classes.

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Contributors

Dr. Lanza conceptualized and designed the study, conducted the analyses, drafted the initial manuscript and reviewed and revised the manuscript; Dr. Leventhal conceptualized and designed the study and reviewed and revised the manuscript; Drs. Cho, Braymiller, Krueger, McConnell, and Barrington-Trimis made contributions to the conception and design of the study and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of interest

No conflicts declared.

Conclusions: Although YAs that predominately used pod devices alongside non-tobacco flavors were most common, YAs characterized by a proclivity toward using many different devices and flavors were appreciably prevalent and smoked and vaped more frequently. Regulations targeting a wide spectrum of vaping products may be optimal in protecting YA health.

Keywords

Cigarette smoking; Device; Flavor; E-cigarette use; Nicotine vaping; Young adults

1. Introduction

Vaping has led to a renormalization of nicotine use among young people (Fairchild et al., 2014; Walley et al., 2019). Nationally representative data show sizeable growth in past 30-day nicotine vaping prevalence from 2017 (6.5%) to 2019 (15.0%) in young adults (Schulenberg et al., 2020). Furthermore, combustible cigarette smoking in U.S. young adults remains unacceptably common (past 30-day prevalence: 11.7% in 2019; Schulenberg et al., 2020). Although the emergence and exponential growth of e-cigarette use in the past decade has substantially changed the landscape of substance use in young adulthood (Perry et al., 2019; Soneji et al., 2017), compared to adolescents, less is known about e-cigarette product characteristics (device type, flavor use) and their relationship with nicotine vaping and cigarette smoking among young adults. Increased focus on young adult e-cigarette use is critical, as life-long tobacco use trajectories often emerge during the transition from adolescence to young adulthood (Palmer et al., 2009; Sussman and Arnett, 2014). Emerging adults' vulnerability to risk-taking behaviors, including nicotine vaping, is likely the result of exposure to social contexts primed for risk-taking behavior (i.e., increased independence, greater peer substance use), as well as a lack of societal normative expectations during this developmental period that may preclude forming an adaptive social identity (Arnett et al., 2014; Schwartz and Petrova, 2019).

While existing federal regulations prevent substantial variation in the types of combustible cigarettes on the market, federal regulations have yet to make a similar impact on e-cigarette use; e-cigarette products available on the market are widely diverse, not yet tightly regulated, and potentially promote young adult tobacco use. To date, a large body of research on e-cigarette product characteristics has focused on flavors (Goldenson et al., 2019). Findings from experimental studies primarily focused on young adults (Audrain-McGovern et al., 2016; Goldenson et al., 2016; Krishnan-Sarin et al., 2017; Leventhal et al., 2019a) indicate that non-tobacco flavored e-cigarette solutions (e.g., fruit or other sweet flavors, mint, or menthol) may decrease the aversive sensory effects of inhaling nicotine (harshness, noxious taste), which may ultimately increase vulnerability to nicotine dependence and promote more frequent nicotine vaping and perhaps use of other tobacco products like combustible cigarettes. The observational literature demonstrates that young adults prefer sweet flavors and mint/menthol compared to older adults (Chen et al., 2019; Soneji et al., 2019). Although no studies have yet examined the association between e-cigarette use frequency and flavor use among young adults, past studies on adolescents indicate that flavor use, particularly sweet or mint/menthol flavors, is associated with continued and increasing e-cigarette use (Audrain-McGovern et al., 2019; Leventhal et al., 2019b). Research evaluating the

relationship between flavor use and cigarette smoking in young adulthood is also scarce. Past studies indicate flavor use increases susceptibility to cigarette smoking among non-smoking adolescents (Chen et al., 2017; Dai and Hao, 2016); however, the only known study to date on young adults found that flavor use was associated with smoking reduction and cessation (Chen, 2018). Although the extent to which the FDA will regulate flavored (non-tobacco), cartridge-based e-cigarettes following their recently announced enforcement strategy is unclear (U.S. Food and Drug Administration, 2020), flavor use in e-cigarettes is still widely available (Cullen et al., 2019) and expected to remain accessible even with the prioritized regulations (Tackett et al., 2020).

Relative to research on flavor use, there is lack of empirical work on e-cigarette device use. Available studies have shown both adolescents and young adults prefer to use later generation devices vs. older devices (Barrington-Trimis et al., 2018; Lin et al., 2020; Shang et al., 2018), but beyond that little is known about device use. Due to the ever-evolving nature of e-cigarette devices, which has changed in popularity from cig-a-likes in 2007 to e-pens/vape pens in 2009, mech mods and box mods in 2012, JUUL and other pod devices between 2015–2017, and most recently disposable pods (e.g., Puff Bar) in 2019, additional studies using contemporary data is needed to understand device use patterns following the introduction of extremely popular pod-style devices (Huang et al., 2019; McKelvey and Halpern-Felsher, 2020). Moreover, because e-cigarette devices vary in their nicotine delivery (Talih et al., 2015), which may result in different physiological and behavioral outcomes, more comprehensive assessment of device use is needed to inform whether specific device use patterns are associated with e-cigarette and cigarette smoking frequency. One recent study reported that young adults using mods vs. e-pens/vape pens had greater odds of cigarette smoking a year later (Barrington-Trimis et al., 2020); another study, albeit focused on adolescents, indicated that multiple device use was associated with non-vaping tobacco use (Krishnan-Sarin et al., 2019). Additional research on device use, particularly among young adults, is likely to prove invaluable for informing tobacco regulatory policies and practices aimed at younger populations.

Given the heterogeneity of the types of devices and flavors of e-cigarettes available on the market, there are thousands of possible combinations of devices and flavors that young adults might be using, which complicates studies of the prevalence and correlates of use of certain e-cigarette products. This is a critical gap to address, as the FDA recently identified the combination of non-tobacco flavors with JUUL/non-JUUL pod-style devices as the target of enforcement of unlawful sales of non-authorized e-cigarettes in the U.S. starting in February 2020 (U.S. Food and Drug Administration, 2020). The FDA views the priority to regulate non-tobacco flavored, cartridge-based e-cigarettes as a balance between reducing e-cigarette use among youth and maintaining potential cessation tools accessible to adult smokers. However, whether more frequent tobacco use in young adults is associated with this specific combination of flavors and devices is unknown, leaving unclear whether this policy will optimally benefit young adults.

The current study used latent class analysis as a data reduction strategy to identify a parsimonious set of combinations of devices and flavors used in a cohort of young adults recruited from the Southern California region. Although we expected large prevalence of

sweet/fruit and mint/menthol flavor use, as well as prominent use of pod-style devices, we did not hypothesize what types of e-cigarette device and flavor use classes would be observed due to the large number of possibilities and general dearth of research on young adult device and flavor use, including their relationship to nicotine vaping and cigarette smoking frequency. Study aims were to: 1) identify the prevalence of distinct patterns of e-cigarette devices and flavors used among young adults; and 2) examine whether greater frequency of nicotine vaping and cigarette smoking were associated with specific device-flavor combinations, and therefore merit priority in e-cigarette regulatory policies to protect young adult health.

2. Methods

2.1. Participants and procedure

The study included data from a prospective cohort study of 3396 adolescents followed into young adulthood. Participants were originally recruited from 10 high schools in the Los Angeles, California metro area and surveyed at six-month intervals from 9th grade (fall of 2013; Wave 1) through 12th grade (spring of 2017; Wave 8). Participants were surveyed again 1-year post-high school (2018–2019; Wave 9). 4100 students were eligible to enroll in the study; parental consent and student assent were obtained for 3396 adolescents (82.8%). The current study used data exclusively from the young adulthood wave (Wave 9). For this wave, participants were contacted after turning 18 years of age and provided written informed consent. Data were collected via online questionnaires; completion rate at this wave was $N = 2552$ (75.1% of original sample). The study was approved by the University of Southern California Institutional Review Board. The analytic sample (N = 550) included young adults that reported any past 30-day nicotine vaping. Sociodemographic characteristics of the analytic sample are provided in Table 1.

2.2. Measures

2.2.1. Vaping device and flavor characteristics—Participants were asked, “In the past 30 days, have you used any of the following electronic nicotine devices? (*Select all that apply*)”. Response choices included: vape pen or pen-like rechargeable device (such as eGO or small startup kit); mod or mech mod rechargeable device; box mod; JUUL; other (non-JUUL) pod mod (e.g., Suorin); disposable device. Six binary items for device use were created; each type of device was coded as 1 = used device in past 30-days and 0 = did not use device in past 30-days.

Flavor used was assessed with the question “During the past 30 days, which types of flavoring have you used with electronic nicotine devices? (Please select all that apply.)”). Responses choices included: flavorless; tobacco flavored; menthol/mint; sweet (fruit, candy, dessert, buttery, etc.); other. Past 30-day JUUL users were asked (“During the past 30 days, which types of flavoring have you used with a JUUL? (Please select all that apply.)”). Response choices included: Virginia tobacco, mint, mango, cucumber, menthol, fruit, crème, classic tobacco. Responses across the two questions were aggregated into three separate binary indicators: tobacco (tobacco flavored, Virginia tobacco, classic tobacco), mint/menthol (menthol/mint, mint, menthol), and sweet/fruit (sweet, mango, fruit, crème), each

coded 1 = used flavor in past 30-days and 0 = did not use flavor in past 30-days. Flavorless and cucumber were excluded due to infrequent selection.

2.2.2. Nicotine vaping and cigarette smoking frequency—Frequency of nicotine vaping and cigarette smoking in young adulthood was assessed with participant self-report. Participants indicated the number of days of nicotine vaping and cigarette smoking in the past 30 days ("In the last 30 days, how many total days have you used an electronic cigarette with nicotine (e-cigs, personal vaporizer, PV, JUUL)?"; "In the last 30 days, how many total days have you used a few puffs of a cigarette (Marlboro, Camel, Newport, etc.)?"). Response categories for both questions (0, 1–2, 3–5, 6–9, 10–19, 20–29, or 30 days) were recoded into quantitative count variables by taking the middle value integer within each response range (0, 2, 4, 8, 15, 25, or 30 days), as in previous work (Goldenson et al., 2017; Leventhal et al., 2019b).

2.2.3. Sociodemographic covariates—Sociodemographic characteristics including age, highest parental education, gender, and race/ethnicity were self-reported. Highest parent education was recoded into a binary variable (≥ *some college* vs. < *some college*). Race/ethnicity was recoded into dummy variables (e.g., 1 = *Asian*, 0 = *non-Asian*) for racial/ethnic groups representing ≥ 10% of the sample (Asian, Hispanic or Latino, White).

2.3. Analysis plan

Latent class analysis (LCA) was conducted to identify classes based on e-cigarette device and flavor use and examine correlates (nicotine vaping, cigarette smoking, sociodemographics) of class membership. In LCA, underlying patterns of observed categorical variables are used to classify individuals with similar responses, behaviors, or characteristics into latent classes (Hagenaars and McCutcheon, 2009; Lanza et al., 2007; Nylund et al., 2007). An increasing number of classes was estimated until an optimal model was identified. Statistical indices, including the Bayesian Information Criterion (BIC; Schwartz, 1978) and Lo-Mendell Rubin Likelihood Ratio Test (LMR LRT; Lo et al., 2001), were used to identify the best-fitting model, in addition to parameter estimates (Collins and Lanza, 2010). Full information maximum likelihood was used to account for missing data. The 3-step approach developed by Vermunt (2010) and popularized by Asparouhov and Muthén (2014) was utilized to examine correlates (covariates) of the identified e-cigarette device and flavor classes. After the best fitting class model was chosen, a most likely latent class variable was created using the latent class posterior probabilities. Logits reflecting the classification uncertainty rate were applied to account for measurement error in the most likely class variable. Following these steps, the most likely class variable was used to assess correlates of class membership. Correlates included past 30-day nicotine vaping frequency, past 30-day cigarette smoking frequency, age, parent education, gender, and ethnicity. Analyses were conducted using Mplus Version 8.4 (Muthén and Muthén, 2017).

3. Results

3.1. Descriptive analyses

Table 1 presents descriptive characteristics of the analytic sample (N = 550) comprised of young adults reporting nicotine vaping in the past 30-days. The average age of participants was M = 19.23 (SD = 0.51) years; close to 70% had parents that attended at least some college. Approximately 51% were female, 37% Hispanic or Latino, 22% Non-Hispanic White, 21% Asian, 8% Native Hawaiian or Pacific islander, 6% Multiracial, 3% Black or African American, and 3% other. On average, participants reported M = 11.94 (SD = 11.33) days of nicotine vaping and M = 1.95 (SD = 5.45) days of cigarette smoking (28.5% of the analytic sample reported past 30-day cigarette smoking). The most commonly used e-cigarette devices were JUUL (56.0%) and non-JUUL pods (44.0%). E-cig/vape pens (33.8%) and mech mods (31.3%) were each used by about a third of participants; the least used devices were box mods (22.7%) and disposable devices (17.5%). Sweet/fruit flavor use was the flavor most frequently reported by participants (65.5%), followed by mint/menthol (47.6%), and tobacco (20.0%).

3.2. Latent class analysis

3.2.1. Model selection—Model fit was evaluated across an increasing number of classes; fit indices indicated that the 3-class model was optimal (Table 2). The Bayesian Information Criterion (BIC; Schwartz, 2978) was the lowest for the 3-class model. The Lo-Mendell-Rubin likelihood ratio test (LMR LRT; Lo et al., 2001) indicated that the 3-class model fit better than the 2-class model, and the 4-class model did not fit any better than the 3-class model. Item-response probabilities, which refer to the likelihood that an individual in a given latent class will report a particular item response, were used to confirm that individuals in each latent class had similar response patterns to the observed indicators and that class response patterns were distinct from each other. Table 3 presents the item-response probabilities observed for each latent class.

3.2.2. Identified classes—As shown in Table 3, the most common class (Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users; 46.7% of the sample) was characterized by young adults reporting JUUL (95%), and to a lesser extent, other non-JUUL pod use (50%). Young adults in this class had a high likelihood of reporting mint/menthol (75%) and sweet/fruit (83%) flavor use. The second most common class (Non-JUUL–Sweet/Fruit Flavor Users; 28.4% prevalence) represented young adults that did not report any JUUL use; otherwise, their device use was diverse and no single device had a high likelihood of use (e.g., 33% e-cig/vape pen, 30% mech mod, 37% non-JUUL pod use). Compared to other flavors, sweet/fruit flavor use was reported by most young adults in this class (85%). The remaining class (Poly-Device–Poly-Flavor Users; 24.9%) had a high likelihood of using all devices and flavors. They had a high likelihood of using every type of device; item response probabilities ranged from 84% to 100% except for disposable devices, which was still higher compared to other classes (50% in this class vs. 11% and 13% in other classes). Young adults in this class had the highest item response probabilities for tobacco (44%), mint/menthol (80%), and sweet/fruit (95%) flavor use.

3.2.3. Correlates of e-cigarette device and flavor classes—Using multinomial logistic regression, correlates (covariates) were simultaneously added into the 3-class model to assess the adjusted odds of class membership based on the past 30-day frequency of nicotine vaping and cigarette smoking variables and sociodemographic variables (age, highest parental education, gender, ethnicity). Two separate multinomial logistic regressions were conducted to evaluate all possible pairwise class comparisons, which are presented in Table 4. Both past 30-day nicotine vaping and cigarette smoking frequency were significantly associated with specific device and flavor class membership. Higher frequencies of past 30-day nicotine vaping and cigarette smoking were reported by young adults in the Poly-Device–Poly-Flavor Users class compared to both Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users (vaping: aOR = 1.36[1.16, 1.59]; $p < .001$; smoking: aOR = 1.25[1.02, 1.54]; $p = .03$) and Non-JUUL–Sweet/Fruit Flavor Users (vaping: aOR = 1.30[1.10, 1.53]; $p < .01$; smoking: aOR = 1.42[1.07, 1.88]; $p = .02$) classes. Participants with higher parental education (≥ some college) had greater odds of belonging to the Poly-Device–Poly-Flavor Users class vs. the Non-JUUL–Sweet/Fruit Flavor Users class (aOR = 2.74[1.18, 6.37]; $p = .02$).

4. Discussion

Using LCA, we were able to identify three distinct patterns of device and flavor use among young adults reporting past 30-day nicotine vaping. The three classes identified (Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users, Non-JUUL–Sweet/Fruit Flavor Users, and Poly-Device–Poly-Flavor Users) highlights the heterogeneity of product combinations used in nicotine vaping in young adulthood, but also provides a parsimonious approach to examining heterogeneity in e-cigarette use. Furthermore, we found that greater frequency of both nicotine vaping and cigarette smoking was linked to specific patterns of use. In contrast to the recent FDA enforcement policy (U.S. Food and Drug Administration, 2020) targeting non-tobacco flavors in JUUL and other pod-style devices, greater frequency of both nicotine vaping and cigarette smoking was linked to poly-device and poly-flavor use, which suggests current regulations are overlooking a significant proportion of young adult e-cigarette users.

A key finding of the current study was that greater frequency of nicotine vaping and cigarette smoking was associated with belonging to a class characterized by indiscriminate use of various devices and flavors (Poly-Device–Poly-Flavor Users; 25% of sample). Given the high likelihood of using all devices, young adults in the Poly-Device–Poly-Flavor Users class appear to be knowledgeable users of a wide variety of e-cigarette devices, ranging from e-cig/vape pens and mech mods/box mods to JUUL and other pod-style devices, including disposable pods. Furthermore, the significant association between higher parental education and membership in this class indicates that this subgroup of young adults may have greater disposable income to purchase multiple types of devices. The link between greater frequency of both nicotine vaping and cigarette smoking to poly-device use extends previous findings indicating multiple device use was a marker of non-vaping tobacco use among adolescents (Krishnan-Sarin et al., 2019). The high likelihood of using multiple devices suggests the focus on regulating cartridge-based (pod-style) devices by the FDA may not be as effective as intended. Furthermore, compared to the other classes, young adults in the Poly-Device–Poly-Flavor Users class had the highest likelihood of using tobacco flavor.

Thus, it seems unlikely that flavor regulations on sweet/fruit or mint/menthol flavors will significantly deter nicotine vaping in those belonging to the Poly-Device–Poly-Flavor Users class as young adults in this class may move to using tobacco flavor exclusively. Although these findings suggest young adults that are using a wide range of devices and flavors vs. a specific combination of device and flavor use may be prime targets for tobacco regulation and intervention, one caveat to keep in mind is that cigarette smoking frequency among this sample of past 30-day nicotine vapers was low (two days on average in the past 30-days); moreover, only 28.5% of the sample reported any cigarette smoking. Therefore, we caution against drawing conclusions until additional research using prospective data or other cohorts is available.

Due to the surge of popularity of JUUL products and other pod-based devices from 2017 to 2019 (Huang et al., 2019; Spindle and Eissenberg, 2018), it was not surprising that the largest proportion (47%) of young adults in the study (surveyed in 2018–2019) were classified into the Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users class. Almost all participants in this class reported JUUL use, and to a lesser extent other pod use. Non-pod use was low overall, which suggests that the characteristics that make pod use unique (stealth, sleek/modern designs, ease of use; Barrington-Trimis and Leventhal, 2018; McKelvey and Halpern-Felsher, 2020) were particularly appealing to this subgroup of nicotine vapers. Due to the use of nicotine salt in pod-based devices, nicotine dependency and abuse liability is a critical concern among pod-based users (Dobbs et al., 2020; Vallone et al., 2020). Additionally, the probability of using mint/menthol or sweet/fruit flavors was close to equal in this class, which corroborates past findings that mint/menthol, not just sweet/fruit flavors, are widely popular among young adults (Chen et al., 2019; Soneji et al., 2019).

In contrast to the other classes, the Non-JUUL–Sweet/Fruit Flavor Users class (28% of sample) was comprised of young adults that did not report any JUUL use. Within this class, device used largely varied and sweet/fruit flavor was predominant. Non-JUUL pods, e-cig/vape pens, and mech mods were reported most, although the likelihood of using any one device was low compared to the other classes. Although tobacco flavor use was not high among any class, the zero probability of tobacco flavor use in the class distinguished by non-JUUL device use suggests that tobacco flavor use in this sample was largely driven by JUUL product use. Like the Poly-Device–Poly-Flavor Users and Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users classes, young adults in the Non-JUUL–Sweet/Fruit Flavor Users had a high probability of sweet/fruit flavor use. The prominence of sweet/fruit flavor use across all e-cigarette device and flavor classes is concerning, as past studies have shown adolescents and young adults that initiate e-cigarette use with sweet/fruit flavors are more likely to continue and escalate their e-cigarette use and initiate cigarette smoking (Chen-Sankey et al., 2019; Dai and Hao, 2016, 2019; Leventhal et al., 2019b). Consequently, irrespective of e-cigarette device and flavor use class membership, continued focus on tobacco use outcomes associated with sweet/fruit flavor use is warranted.

Limitations of this study should be considered when interpreting findings. The use of a sample specific to the Southern California region limits generalizability of findings to other regions; however, a regionally-specific sample increases the likelihood participants were

experiencing similar tobacco regulatory policies and trends in e-cigarette use during the period of assessment. The study also relied on self-report of e-cigarette use characteristics, nicotine vaping, and cigarette smoking, although self-report is the most common method of measuring substance use behaviors. Findings linking nicotine vaping and cigarette smoking to e-cigarette device and flavor classes are cross-sectional, thus, it is unclear whether distinct patterns of device or flavor use predict greater frequency of nicotine vaping and cigarette smoking or if greater frequency of these substance use behaviors influence the device and flavor patterns identified. Prospective analysis of this sample was not possible as detailed level of device use was first measured during the young adulthood wave. It is also important to note this study represents a specific timepoint within the e-cigarette regulation landscape. Since data were collected, JUUL has eliminated the sale of all flavor cartridges except tobacco and menthol; this has been met with a growing demand for disposable e-cigarette products available in a variety of flavors as well as flavored pod attachments (Cwalina et al., 2020). Also, although this study was not able to differentiate between mint and menthol flavor use, JUUL's decision to eliminate mint but not menthol in conjunction with an abundant literature highlighting the unique effect of menthol of tobacco use (Rath et al., 2016; Wickham, 2015) highlights the need to distinguish menthol from other flavors in future work. The rapidly evolving nature of e-cigarette product manufacturing, marketing, and sales speaks to the importance of continuing this line of research on a more frequent and larger scale.

Identified e-cigarette device and flavor classes show that e-cigarette use among young adults is not a homogenous activity; some young adults limit their e-cigarette use to JUUL/pod-based devices and previously identified popular flavors (mint/menthol and sweet/fruit), others gravitate towards sweet/fruit flavors but without a strong tie to any type of device, and still other young adults report a high probability of using a wide assortment of devices and flavors. Although the FDA is prioritizing regulation on flavored (non-tobacco), cartridge-based (pod-style) e-cigarettes in hopes of striking a balance between younger populations engaging in e-cigarette use and adult smokers attempting cessation, the current study places doubt on whether targeting specific flavor and device combinations will have the desired impact for the health of young adults. The FDA enforcement strategy does target the most common class of young adult e-cigarette users in this study (Any Pod–Mint/Menthol or Sweet/Fruit Flavor Users), but fails to address the higher frequency of nicotine vaping and cigarette smoking reported among young adults using a wide array of devices and flavors (Poly-Device–Poly-Flavor Users). Although additional research is needed to determine whether distinct patterns of device and flavor use predict to continued or escalating nicotine vaping and cigarette smoking across young adulthood, the current study indicates a broader strategy targeting devices and flavors may be warranted to protect young adult health.

Acknowledgments

Role of funding source

This project was supported in part by Tobacco Centers of Regulatory Science (TCORS) award U54CA180905 from the National Cancer Institute (NCI) and the US Food and Drug Administration (FDA), award number R01CA229617 from the NCI, award number 27-IR-0034 from the California Tobacco-Related Disease Research Program (TRDRP), and award number K01DA042950 and K24DA048160 from the National Institute on Drug Abuse (NIDA).

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Table 1

Descriptive characteristics of young adults reporting past 30-day nicotine vaping ($N = 550$).

Variable	*N*(%) or *Mean* ± *SD*
Age (years)	19.23 ± .51
Parent highest education	
≥Some college	384 (69.8%)
<Than some college	104 (18.9%)
Unknown	62 (11.3%)
Gender	
Female	279 (50.7%)
Male	271 (49.3%)
Ethnicity	
American Indian or Alaskan native	3 (0.5%)
Asian	116 (21.1%)
Black or African American	16 (2.9%)
Hispanic or Latino	202 (36.7%)
Native Hawaiian or Pacific Islander	43 (7.8%)
White	119 (21.6%)
Multiracial	34 (6.2%)
Other	15 (2.7%)
Unknown	2 (0.4%)
Nicotine vaping	
Past 30-day use frequency	11.94 ± 11.33 days
Cigarette smoking	
Past 30-day use (any)	157 (28.5%)
Past 30-day use frequency	1.95 ± 5.45 days
Device use	
E-eig/vape pen	186 (33.8%)
Mech mod	172 (31.3%)
Box mod	125 (22.7%)
JUUL	308 (56.0%)
Pod (non-JUUL)	242 (44.0%)
Disposable	96 (17.5%)
Flavor use	
Tobacco	110 (20.0%)
Mint/menthol	262 (47.6%)
Sweet/fruit	360 (65.5%)

Table 2

Latent class model fit indices.

Classes	Log likelihood	Free parameters	BIC[a]	Adjusted BIC[b]	AIC[c]	LMR LRT *p*-value for k-1[d]	Entropy
1	−2340.71	9	4736.71	4708.14	4699.43	N/A	N/A
2	−2125.72	19	4368.14	4307.84	4289.44	<.001	.88
3	−2057.68	29	4293.49	4201.45	4173.37	<.001	.87
4	−2039.30	39	4318.13	4194.36	4156.59	.08	.85
5	−2022.55	49	4346.06	4190.54	4143.10	.10	.83

[a]BIC = Bayesian information criterion.

[b]sample-size adjusted Bayesian information criterion.

[c]AIC = Akaike information criterion.

[d]LMR LRT = Lo-Mendell-Rubin likelihood ratio test, *p*-value for *k*-1 refers to significant improvement in model fit between the class (*k*) and the class preceding it (*k*-1).

Table 3

Item-response probabilities of young adult e-cigarette device and flavor classes ($N = 550$).

	Any pod–mint/ menthol or sweet/ fruit flavor users	**Non-JUUL–sweet/ fruit flavor users**	**Poly-device–poly-flavor users**
Class prevalence	46.7%	28.4%	24.9%
Item	Item-response Probabilities		
Past 30-day device use			
e-cig/vape pen	.27	.33	.84
Mech Mod	.11	.30	1.00
Box Mod	.05	.17	.90
JUUL	.95	.00	.96
Pod (non-JUUL)	.50	.37	.88
Disposable	.13	.11	.50
Past 30-day flavor use			
Tobacco	.35	.00	.44
Mint/Menthol	.75	.31	.80
Sweet/Fruit	.83	.85	.95

Table 4

Estimated Adjusted Odds Ratios (aOR) of e-cigarette device and flavor class membership based on correlates.

	Poly-device–poly-flavor users (vs. any pod–mint/menthol or sweet/fruit flavor users)	**Poly-device–poly-flavor users (vs. non-JUUL–sweet/fruit flavor users)**	**Non-JUUL–sweet/fruit flavor users (vs. any pod–mint/menthol or sweet/fruit flavor users)**
	aOR (95%CI)	**aOR (95%CI)**	**aOR (95%CI)**
Tobacco product use frequency			
Past 30-day nicotine vaping	1.36 (1.16–1.59) ***	1.30 (1.10–1.53) **	1.05 (.91–1.20)
Past 30-day cigarette smoking	1.25 (1.02–1.54) *	1.42 (1.07–1.88) *	.89 (.67–1.17)
Sociodemographic covariates			
Age	.83 (.47–1.46)	.84 (.47–1.53)	.98 (.59–1.62)
Highest parental education level	1.64 (.72–3.72)	2.74 (1.18–6.37) *	.60 (.32–1.13)
Male vs. Female	1.64 (.91–2.95)	1.25 (.67–2.33)	1.31 (.78–2.21)
Asian (vs. non-Asian)	1.95 (.79–4.81)	1.76 (.65–4.80)	1.11 (.46–2.69)
Latino (vs. non-Latino)	1.07 (.47–2.44)	.78 (.31–1.96)	1.37 (.64–2.93)
White (vs. non-White)	1.05 (.45–2.43)	.69 (.27–1.79)	1.52 (.67–3.46)

Highest parental education level = some college or more vs. less than some college.

* $p < .05$.

** $p < .01$.

*** $p < .001$.