



## Adult harm perceptions, purchase, and use related to synthetic vs. tobacco-derived nicotine vaping products: A mixed-methods study

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### ABSTRACT

**Objective:** Synthetic nicotine (SN) e-cigarettes emerged on the market as an alternative to tobacco-derived nicotine (TDN) vaping products. It is critical to understand the harm perceptions, purchase, and use of SN vs. TDN e-cigarettes.

**Methods:** From November 2021 to February 2023, we conducted intercept interviews with 263 adult customers at 37 vape shops in Southern California. Self-reported use and harm perceptions towards SN vs TDN e-cigarettes were examined. A qualitative analysis of researcher-obtained photographs of vaping items just purchased by customer participants was conducted.

**Results:** Past 30-day SN e-cigarette use was reported by 44 (16.7 %) customers. Past 30-day SN e-cigarette users vs. non-users reported vaping on more days in the past month (29.3 vs. 26.1 days,  $p = 0.02$ ). Overall, 23.8 % of participants perceived SN e-cigarettes as less harmful than TDN ones; never-smoking vapers and dual users perceived SN e-cigarettes as less harmful than salt-based TDN e-cigarettes. Among 44 customers who purchased SN products (verified through qualitative analysis of photographs), only 13 (29.6 %) self-reported using SN products in the past month, while 5 (11.4 %) indicated they were not aware of the existence of SN products. Most SN vaping products (71.4 %) displayed a modified “tobacco-free” warning label.

**Conclusions:** Misperceptions about SN e-cigarettes were documented in this study, including the perception that SN is either less or more harmful than TDN. Further, some customers may be unknowingly purchasing and using SN e-cigarettes. Regulating “tobacco-free nicotine” terminology in SN vaping products marketing is suggested. SN product labeling should not imply that SN is safe/safer than TDN.

### 1. Introduction

In 2016, the U.S. Food and Drug Administration (FDA) extended its regulatory authority (“Deeming Rule”) to electronic cigarettes (e-cigarettes) by classifying them as tobacco products because they contained tobacco-derived nicotine (TDN) (US Food and Drug Administration, 2018). The rule enabled the FDA to monitor and regulate the manufacturing, distribution, and marketing of e-cigarettes, including specific components like atomizers and e-liquid, as well as other tobacco products such as cigars, hookah, and pipe tobacco (US Food and Drug

Administration, 2018; Meza et al., 2022). This regulation prohibited free samples of e-cigarettes and other tobacco products and mandated the inclusion of health warnings on product packaging (US Food and Drug Administration, 2018). Subsequently, tobacco manufacturers introduced synthetic nicotine (SN) vaping products, also referred to as “tobacco-leaf free” and “tobacco-free nicotine”, which is reported by manufacturers to be synthesized in the lab and not extracted from the tobacco plant (Jordt, 2023; Morean et al., 2022). SN vaping products are sold as either closed-system disposable devices or pods or stand-alone e-liquids used in conjunction with open-system refillable devices. SN e-

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cigarettes are also extensively marketed in fruit and cooling flavors, which may increase product appeal, especially among youth and young adults (Cwalina et al., 2021; Kong and Suchitra, 2021). In March 2022 the FDA asserted its authority over products containing nicotine from any source, including SN e-cigarettes (US Food and Drug Administration, 2022). While it is still uncertain whether these products will remain on the market, research on the perceptions and use patterns of e-cigarette consumers who purchase and use SN vs TDN products is needed to better understand the knowledge gaps associated with both types of products and how they are similar or different.

There is limited knowledge about the health implications of TDN versus SN. TDN primarily consists of the (S)-nicotine (>99 %) enantiomer, derived from the tobacco plant. In contrast, SN typically contains a racemic mixture of both (S)- and (R)-nicotine enantiomers (Salam et al., 2023). Preliminary findings suggest that S-nicotine is a more potent agonist of nicotinic receptors than (R)-nicotine (Jordt, 2023). However, as of now, there is no systematic research indicating whether e-cigarettes containing SN are less or more harmful compared to vaping products that contain TDN (Jordt, 2023; Salam et al., 2023). Despite the lack of evidence, manufacturers of SN e-cigarettes often market their products as “cleaner”, “purer”, “higher quality” and “tastier” compared with TDN e-cigarettes (Kong and Suchitra, 2021; Davis et al., 2023). Such claims could lead consumers to mistakenly perceive SN e-cigarettes as lower-risk compared to those containing TDN.

A recent online randomized between-subjects experiment found that “tobacco-free” vs “regular” nicotine labeling on e-cigarettes is associated with lower harm perceptions and greater intentions to use SN vaping products (Chen-Sankey et al., 2021). However, the data was limited to the non-tobacco-using young adult population and focused solely on the effects of Puff Bar’s ‘tobacco-free nicotine’ claims. While some research suggests SN marketing as “tobacco free” could imply to customers that these products are less harmful than TDN vaping products because of claims that SN lacks impurities contained in tobacco (Seidenberg and Kaufman, 2022); it is plausible that other consumers may perceive SN as “less natural” (lab-produced vs. plant-cultivated), and less safe than TDN. Since lower harm perceptions could lead to increased use, research comparing harm perceptions of SN vs. TDN e-cigarettes among the adult tobacco-using population is warranted. Moreover, given that salt- vs. free-base e-cigarette use is associated with improved appeal and sensory experience of vaping (Leventhal et al., 2021); it is important to consider the formulation of nicotine when comparing harm perceptions of SN and TDN e-cigarettes. Considering that SN vaping products are frequently advertised and sold in sweet, fruit, and “ice” flavors, it is plausible that SN e-cigarette users have a higher preference for these flavors (Kong and Suchitra, 2021). Among U.S. young adults (18–25 years), lifetime SN e-cigarette users (34 %) had a greater preference for fruit and cooling flavors compared to those who had never tried SN products; nonetheless, the extent of flavor preference among older SN vapers remains unknown (Davis et al., 2023).

Brick-and-mortar retailers (i.e., vape shops) remain one of the primary acquisition sources for vaping products (Gaiha et al., 2021). To better understand consumers’ knowledge of SN and TDN products, in this mixed methods study, we examined relative harm perceptions and use behaviors of SN vs TDN e-cigarettes among adult vape shop customers aged 18 to 66 years old. Customers were interviewed immediately after they exited vape shops, leveraging the immediate context where consumers’ perceptions, attitudes, beliefs, and purchasing motives are highly salient, which minimizes retrospective bias. As a result, this methodology is expected to produce results with heightened validity and depth, accurately reflecting the perspectives of vape customers. We explored SN misperceptions and use, and whether SN users preferred fruit and/or cooling flavors compared to those that did not use SN products. In addition, we conducted a qualitative analysis of photographs of purchased vaping items to differentiate between SN and TDN e-cigarette purchases and documented whether customers were aware of the type of nicotine in the products they purchased.

## 2. Methods

### 2.1. Participants and procedures

Similar to previous studies (Sussman et al., 2014; Huh et al., 2023; Strong et al., 2019); we generated a list of vape shops in racially/ethnically diverse neighborhoods. From November 2021 to February 2023, a team of two to three trained data collectors visited 37 vape shops in Southern California (between 10 am and 5 pm) and approached all customers as they exited the vape shop (n = 519). Eligible customers (those who had vaped in the past 30 days) were invited to participate in a 15-minute interview. Data collectors followed scripts and verbally administered structured questionnaire items. At the end of the survey, we also took photographs of vaping items that customers purchased at the vape shop. Customers provided verbal consent for this anonymous survey. Participants received a \$35 gift card. A total of 491 eligible customers were invited to participate (28 customers were ineligible); 263 of them (53.6 %) agreed and completed the survey. A total of 245 photos of vaping items (device, and/or e-liquid) purchased by 184 customers were analyzed. This study was approved by the USC Institutional Review Board (#HS-18-00732).

### 2.2. Measures

**Demographics.** Participants reported their gender, age, and ethnicity.

**SN e-cigarette use.** Past 30-day SN e-cigarette use was measured with the question: *In the past 30 days, on how many days did you use synthetic nicotine vaping product (e.g., nicotine not made from tobacco, also called “tobacco-free nicotine”)?* (1–30 days). Responses were further dichotomized, with answers of anything other than “0” being considered as (self-reported) past 30-day SN e-cigarette use (vs. SN e-cigarette non-use).

**Other tobacco use.** Lifetime combustible cigarette use was assessed with the question, *Have you smoked at least 100 cigarettes in your entire life?* (Yes/No). To examine past 30-day combustible tobacco use (cigarettes, cigars or cigarillos, hookah, and/or pipe tobacco) we asked the following questions: *In the past 30 days, on how many days did you use cigarettes/hookah/ cigars or cigarillos/ pipe tobacco?* (1–30 days). Participants were categorized into three tobacco user groups: never smoking vapers (e-cigarette only users; currently using e-cigarettes and are not lifetime or past 30-day combustible cigarette smokers), former cigarette smokers (switchers; had used cigarettes in their lifetime but are no longer current smokers), and dual users (currently using both e-cigarettes and other combustible tobacco products).

**E-cigarette use characteristics.** The most frequently used type of e-cigarette device was assessed by asking participants: *What type of e-cigarette device do you use most often?* (pen, box mod, disposable pod, free-base and salt-base refillable pod). Preferred device/e-liquid nicotine level was assessed by asking: *How many mg per ml of nicotine does your favorite brand/flavor have?* (Open-ended, e.g., 0, 3, 6, 9, 25, 50 mg/ml). Participants’ device/e-liquid flavor preference was assessed with the open-ended question, *What is your preferred flavor?*. Responses to this open-ended item were analyzed by two experienced coders (Cohen’s kappa ranging from 0.90 to 1.00); three categories were created: fruit or cooling, dessert/candy, other (e.g., tobacco, etc.).

**Harm perceptions** of TDN vs. SN e-cigarettes were assessed by asking *How harmful to your health do you think each of the following nicotine-containing products are on a scale of 1-to-10 (free-base e-cigarettes, salt-base e-cigarettes, SN e-cigarettes)?* (10-point scale, ranging from 1 = no danger/ quite safe to 10 = dangerous/not safe at all). Some customers were unaware of SN vaping products and could not respond to harm perception of SN scale item; they were coded as “unaware of SN vaping products”. In addition, a subsample of participants (N = 70; surveyed on or after September 1, 2022) were asked to directly compare TDN and SN e-cigarettes by asking, *In your opinion, compared to a vaping product*

made from tobacco-derived nicotine, how harmful to your health is a vaping product that contains synthetic nicotine (lab-created)?". Further, participants were asked to provide rationale supporting their response (opened).

**Photographs of customers' purchases.** The authors worked together to become familiar with the photos and created a codebook. The unit of analysis was the photo of the purchased item (see supplementary Fig. 1). To ensure consistency, they cross-referenced the products using retailer websites. Any discrepancies were resolved through discussion. The first author served as the arbitrator, resolving disagreements. Two trained members of the research team coded a subsample ( $n = 61$ , 25 % of the analytic sample) to determine reliability (Cohen's kappa ranging from 0.96 to 1.00).

We coded photographs for (a) *product type* (device, pod, and/or e-liquid; all that applies); (b) *device type* (disposables vs. other [e.g., pod mod]); (c) *product nicotine level* (e.g., 0, 3, 6, 9, 25, 50 mg/ml); (d) *type of nicotine* (SN vs. TDN); (e) *type of warning label*: standard ("Warning: This product contains nicotine. Nicotine is an addictive chemical.") vs. "tobacco-free" ("Warning: This product contains tobacco-free/synthetic nicotine. Nicotine is an addictive chemical.") or "Warning: This product contains nicotine not derived from tobacco. Nicotine is an addictive chemical"). To determine if customers are aware they are purchasing SN products, we compared our qualitative analysis results (specifically, whether an SN product was purchased [Yes/No]) to survey responses on past 30-day SN e-cigarette use (Yes or No) and awareness of SN products (Yes/No; see harm perceptions sub-section).

### 2.3. Data analysis

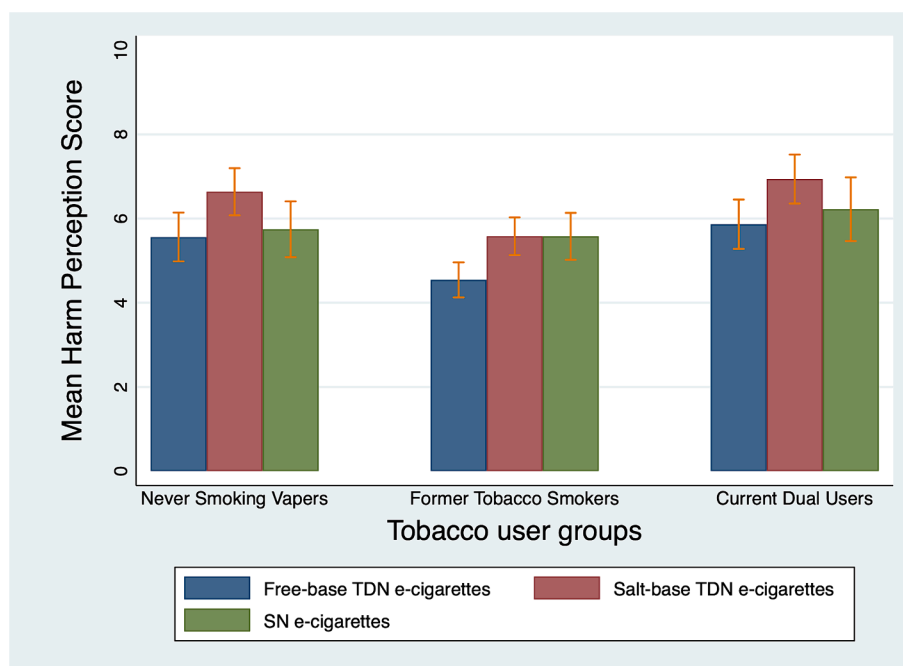
We evaluated bivariate associations between self-reported past 30-day SN e-cigarette use (vs. non-use) and other study variables, using Pearson's chi-square tests for categorical variables and t-tests for continuous variables. Further, we used the repeated measures multilevel modeling approach to test the tobacco user group (never smoker, dual-user, or former cigarette users)  $\times$  product type (salt-base TDN, free-base TDN, or SN e-cigarettes) interaction on self-reported harm perception outcome (customer level).

Completed open-ended responses ( $n = 70$ ) regarding why customers believe that TDN e-cigarettes are more/less/equally harmful than SN e-cigarettes were analyzed qualitatively by two experienced coders using an inductive approach (Cohen's kappa ranging from 0.90 to 1.00; all responses were double-coded); the aim of this approach was to condense the raw text-based data into a summary format and report the underlying themes evident in the data. Saturation was reached after 40 interviews and 10 themes emerged (Hennink et al., 2017). A single customer's response could fall into multiple themes.

Finally, qualitative analysis of 245 photographs of (prefilled) vaping devices, pods, and/or e-liquids purchased by 184 customers was conducted (27 customers did not make any purchase, 52 customers purchased other vaping related paraphernalia [coils, mouth tips, batteries, etc.]). Participant accrual, sample size, and exclusions from the analytic sample are depicted in Fig. 1 of Supplementary Material. Statistical significance was set at  $p < 0.05$  (two tailed). Benjamini-Hochberg multiple-testing corrections were applied to control the false-discovery rate at 0.05. All statistical analyses were conducted using Stata software (v 17.0; StataCorp).

### 3. Results

Of the 263 customers surveyed, 177 (67.3 %) were males, with a mean age of 32.8 years ( $SD = 10.7$ , range 18–66). Most participants ( $n = 217$ , 82.5 %) had vaped daily in the past month; 66 (25.1 %) were never smoking vapers, 129 (49.0 %) were former cigarette smokers, and 68 (25.9 %) were current dual users. Past 30-day SN e-cigarette use was reported by 44 (16.7 %) customers. Other participant characteristics are presented in Table 1. On average, self-reported past 30-day SN e-cigarette users vs. non-users (defined as those who reported using TDN e-cigarettes in the past 30 days but not SN products) had vaped on more days in the past month (29.3 [3.2] days vs. 26.1 [8.5] days,  $p = 0.02$ ). In addition, self-reported past 30-day SN e-cigarette users vs. non-users had a higher preference for fruit or ice flavors (31 [70.5 %] vs. 103 [47.0 %],  $p < 0.01$ ). SN e-cigarette use did not vary by tobacco use status, or any other sociodemographic variable. Notably, 46 (17.5 %) customers were not aware about SN vaping products.



**Fig. 1.** Vape shop customers' ( $N = 263$ ) harm perceptions towards free-base, salt-base, and synthetic nicotine e-cigarettes, as reported by three tobacco users groups. Note: Harm perceptions were measured using a 10-point scale, where 1 – no danger/ quite safe and 10 – dangerous/not safe at all. Error bar represents the 95 % confidence interval.

**Table 1**  
Descriptive characteristics of sample vape shop customers surveyed in Southern California, 2021–2023.<sup>a</sup>

Study variables	Total n = 263
<b>Demographics</b>	
Age, mean (SD)	32.8 (10.7)
Male, n (%)	177 (67.3)
Race/Ethnicity, n (%)	
- Asian	57 (21.7)
- African American/Black	6 (2.3)
- Hispanic/Latino	62 (23.6)
- White	103 (39.1)
- Other	35 (13.3)
<b>Use behaviors</b>	
Daily-e-cigarette use, n (%)	217 (82.5)
Preferred nicotine level (mg/ml), mean (SD)	32.5 (21.1)
Past 30-day SN e-cigarette use, n (%)	44 (16.7)
<b>Tobacco user groups, n (%)<sup>a</sup></b>	
- E-cigarette only user	66 (25.1)
- Former cigarette smoker	129 (49.0)
- Dual user	68 (25.9)
<b>E-cigarette device type used in past 30 days, n (%)</b>	
- Disposable pod	125 (47.5)
- Refillable pod (free-base or salt-base)	80 (30.4)
- Other (box mod or vape pen)	58 (22.1)
<b>Flavor preference, n (%)</b>	
- Fruit or Ice	134 (51.0)
- Dessert/Candy	37 (14.1)
- Other Flavors	23 (8.8)
<b>Harm perception, mean (SD)<sup>b</sup></b>	
- SN e-cigarettes	5.8 (2.8)
- Free-base TDN e-cigarettes	5.2 (2.5)
- Salt-base TDN e-cigarettes	6.2 (2.5)

SN, Synthetic Nicotine; TDN, Tobacco-derived Nicotine.

Former cigarette smokers: had used cigarettes in their lifetime but are no longer current smokers.

Dual users: currently using both e-cigarettes and other combustible tobacco products.

<sup>a</sup> E-cigarette only users: currently using e-cigarettes and are not lifetime or past 30-day combustible cigarette smokers.

<sup>b</sup> On a scale from 1 to 10, where 1 – no danger/ quite safe and 10 – dangerous/ not safe at all.

### 3.1. Harm perception

Overall, free-base TDN e-cigarettes were perceived as less harmful (5.2 [2.5] vs. 5.8 [2.8],  $p < 0.01$ ) than SN e-cigarettes, while salt-base TDN e-cigarettes were perceived as more harmful than SN e-cigarettes (6.2 [2.5] vs. 5.8 [2.8],  $p = 0.02$ ). Tobacco user group  $\times$  product type interaction was significant: never smoking vapers (5.7 [2.5] vs. 6.6 [2.3],  $p = 0.001$ ) and dual users (6.2 [2.8] vs. 6.9 [2.4],  $p = 0.01$ ) perceived SN e-cigarettes as less harmful than salt-base TDN e-cigarettes, while former tobacco smokers perceived SN e-cigarettes as more harmful than free-base TDN e-cigarettes (5.6 [2.9] vs. 4.5 [2.4],  $p < 0.001$ ; see Fig. 1).

### 3.2. Open-ended responses regarding harm perceptions of SN vs. TDN vaping products

Customers' ( $n = 70$ ) harm perceptions towards TDN vs. SN e-cigarettes were evaluated based on the responses to the open-ended item to explain their rationale: 20 (41.4 %) believed that both products are equally harmful, 15 (21.4 %) indicated that SN e-cigarettes are less harmful than TDN e-cigarettes, 19 (27.2 %) mentioned that TDN e-cigarettes are less harmful than SN e-cigarettes, and 7 (10.0 %) customers reported that they don't know the answer. Vape shops customers often mentioned that lab-based products are more harmful and/or less natural than plant-cultivated ones (17 [24.3 %]), that both products are the same (13 [18.6 %]), and that both products are harmful (9 [12.9 %]). Other responses, descriptive characteristics, and coding criteria are

presented in Table 2.

### 3.3. Analysis of photos

Qualitative analysis of photographs revealed that 117 (44.5 %) of the vape shop customers in our sample purchased a vaping device, 76 (28.9 %) bought an e-liquid, and 3 (1.1 %) purchased a replacement pod. Most devices purchased by customers ( $n = 108$ , 92.3 %) were disposables: 78 (66.7 %) were salt-based TDN disposable devices and 30 (25.6 %) were SN disposables. Meanwhile, 9 customers (7.7 %) purchased other types of devices (e.g., box mods, vape pens) compatible with free-base SN and/or TDN e-liquids. A total of 44 (16.7 %) customers purchased vaping devices with SN ( $n = 30$ ) and/or standalone SN e-liquids used for refillable open system devices ( $n = 26$ ).

On average, SN vaping products purchased by customers contained higher concentration of nicotine than TDN e-cigarette products (41.3 mg/ml vs. 34.1 mg/ml,  $p = 0.02$ ). Most SN vaping products ( $n = 40$ , 71.4 %) displayed a modified tobacco-free warning label, 13 (23.2 %) displayed standard warning label, while 3 (5.4 %) did not contain any warning label on the package (see Fig. 2). Of the 44 customers who purchased SN products, only 13 (29.6 %) reported using an SN e-cigarette in the past 30 days, while 5 (11.4 %) indicated they were not aware of SN vaping products.

## 4. Discussion

This is one of the first studies to explore relative harm perceptions, purchase, and use behaviors of SN vs TDN e-cigarettes among adult vape shop customers. Vape shop customers' misperceptions about SN e-cigarettes were documented in this study, including the perception that SN is either less or more harmful than TDN. Among customers who purchased SN e-cigarette products, only 30 % self-reported their past 30-day use, while 11 % were unaware of SN vaping products. This suggest that that some customers may be unknowingly purchasing and using SN e-cigarettes. SN e-cigarette users had a greater preference for fruit and cooling flavors and had vaped on more days in the past month, compared to SN e-cigarette non-users. Further, SN vapes often displayed misleading "tobacco-free" warning labels and are sold in high nicotine concentrations.

Lower risk perceptions about SN vaping products were documented in our study; over 20 % of participants perceived SN e-cigarettes as less harmful than TDN ones. Notably, never-smoking vapers and dual users perceived SN e-cigarettes as less harmful than salt-base TDN e-cigarettes. This observation is concerning, indicating a heightened vulnerability among these tobacco users who may be more susceptible to the marketing strategies utilized by SN manufacturers. These strategies can shape customer perceptions, especially since many of these novel products are often marketed as "tobacco-free", "cleaner", and "tastier", which could be misinterpreted by consumers as lower risk products than TDN e-cigarettes (Kong and Suchitra, 2021; Davis et al., 2023; Seidenberg and Kaufman, 2022). Such descriptions could lead consumers to mistakenly view SN e-cigarettes as lower-risk products compared to TDN e-cigarettes. Furthermore, the majority (71 %) of SN e-cigarette products bought by customers in our study featured a modified "tobacco-free" warning label. Our findings highlight the need for regulatory authorities to address "tobacco-free nicotine" terminology or other marketing tactics in product labeling and advertising that somehow might mislead consumers to perceive SN products as less harmful than TDN products (Keller-Hamilton et al., 2023); even though there is no clear evidence to suggest that e-cigarettes containing SN are any less toxic (Jordt, 2023; Salam et al., 2023). Clear and concise warning labels are necessary to ensure that consumers understand the potential risks of all nicotine-containing products, regardless of how they are derived.

SN e-cigarette users reported a higher frequency of vaping in the past month compared to SN e-cigarette non-users. In addition, SN vs. TDN vaping products purchased by customers contained higher nicotine

**Table 2**

Vape shop customers' open-ended responses (n = 70) on harm perceptions of synthetic nicotine vs. tobacco-derived nicotine vaping products: themes, definitions, and selected paraphrased responses.<sup>a</sup>

Theme	N (%)	Definition	Paraphrased response
1) Lab-based products are harmful and/or are not natural	17 (24.3)	Responses mentioning that lab-based/synthetic products are more dangerous and/or more potent than naturally grown ones (including mentions that lab products are unsafe or unhealthy). May also mention that SN products are not natural (e.g., man-made) than plant-cultivated ones	<i>"Anything created in the lab is not good for your health"</i> <i>"One cannot replicate nature"</i>
2) Both products are same	13 (18.6)	Responses mentioning that both TDN and SN vaping products contain same chemicals, including suggestions that they are essentially the same products	<i>"Both products contain nicotine, same elements"</i>
3) Don't know	10 (14.3)	Mentions of being not familiar with SN products, including "don't know the answer" responses	<i>"Never used SN e-cigarettes and can't judge"</i>
4) Both products are harmful	9 (12.9)	Responses mentioning that both TDN and SN are equally as harmful/dangerous	<i>"All nicotine products are bad either way"</i>
5) Uncertainty about SN manufacturing process	7 (10.0)	Mentions of being uncertain about what is inside the SN vaping products and how they were manufactured (including mentions that more additives are added to the SN products)	<i>"Never know what is in SN e-cigarettes"</i>
6) SN are safer/have better quality control	6 (8.6)	Responses mentioning that SN is safer than TDN products, including mentions that SN products have more control on ingredients and/or better manufacturing process	<i>"Science is safer"</i>
7) Limited Research	6 (8.6)	Responses mentioning that there is not enough research on SN products	<i>"Not enough research on both products"</i>
8) Misinformation about SN products	4 (5.7)	Responses containing any misinformation about SN products	<i>"Both products are FDA approved"</i> <i>"SN is not actual nicotine"</i>
9) SN tastes better/is cleaner than TDN	3 (4.3)	Responses mentioning that SN vaping products taste or smell better than TDN (including mentions that SN is "cleaner" than TDN).	<i>"SN e-cigarettes taste better than regular tobacco vapes"</i>
10) Distrust in SN products	3 (4.3)	Mentions of distrust in SN products	<i>"SN is fake stuff"</i>

SN, Synthetic Nicotine; TDN, Tobacco-derived Nicotine.

<sup>a</sup> Customers were asked to explain their reasons for why they believe that TDN e-cigarettes are more, less, or equally harmful compared to SN e-cigarettes. Their responses were qualitatively analyzed, and saturation was achieved with 10 distinct themes. A single customer's response could fall into multiple themes.

concentration. This increased nicotine level in SN products may significantly impact their usage patterns. Evidence suggests that higher nicotine concentrations in vaping products can be more reinforcing, potentially making them more addictive and appealing to consumers (Gades et al., 2022). Consequently, this might explain the increased vaping frequency observed among SN e-cigarette users. Further, in line with previous research conducted among U.S. young adults, SN e-cigarette users preferred fruit and cooling flavors (Davis et al., 2023). Fruit and cooling flavors increase the attractiveness of e-cigarettes in young adults while mitigating the unpleasant sensory characteristics of nicotine (Leventhal et al., 2020). Taken together, our findings underscore the need for implementing comprehensive regulations on flavors and nicotine content in SN vaping products.

Over 17 % of the customers in our sample were not aware of SN vaping products. Further, our study has shed light on a concerning trend where vape shop customers may be unknowingly purchasing and using SN e-cigarettes. As the market for e-cigarettes recently expanded to include SN products (Kong and Suchitra, 2021; Chen-Sankey et al., 2021); consumers may lack awareness of the existence of such products. This lack of consumer awareness can have serious implications for public health, as the potential risks associated with SN e-cigarette usage remain unknown (Jordt, 2023; Salam et al., 2023). As the e-cigarette market continues to evolve, efforts should focus on improving product labeling and conducting awareness campaigns to ensure consumers are well-informed about the potential risks associated with SN e-cigarettes.

#### 4.1. Limitations

The results of our study might not generalize to e-cigarette users who have different demographic characteristics, live in different geographic areas, or obtain their e-cigarette products from other sources (e.g., online). Social desirability and recall biases may have affected participants' self-reports. The harm perception scale item for SN e-cigarettes did not differentiate between salt-based and free-base nicotine formulations. For more accurate estimates, future studies on harm perceptions of SN vs. TDN e-cigarettes should consider the nicotine formulation (salt-based vs. free-base) in both products.

## 5. Conclusions

Our study provides important information regarding relative harm perceptions and use behaviors of SN vs TDN e-cigarettes among regular adult vapers. Effective oversight and education campaigns are necessary to protect public health, prevent misleading claims, and promote informed decision-making among consumers. Future research should evaluate the long-term health effects and nicotine dependence associated with the use of SN vs TDN products.

#### CRedit authorship contribution statement

**Artur Galimov:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Adam M. Leventhal:** Writing – review & editing, Validation, Supervision, Resources, Funding acquisition, Conceptualization. **Josef Hamoud:** Writing – review & editing, Writing – original draft, Investigation. **Leah Meza:** Writing – review & editing, Supervision, Project administration, Investigation, Data curation, Conceptualization. **Jennifer B. Unger:** Writing – review & editing, Validation, Supervision, Resources, Funding acquisition. **Jimi Huh:** Writing – review & editing, Visualization, Supervision, Methodology. **Lourdes Baezconde-Garbanati:** Writing – review & editing, Resources, Funding acquisition. **Steve Sussman:** Writing – review & editing, Validation, Resources, Funding acquisition, Conceptualization.



Fig. 2. Examples of vape shop customer purchases: types of warning labels (standard vs. modified) on synthetic nicotine vaping product packaging.

### 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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#### Role of Funder

NCI, or the FDA had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

#### Data Availability.

Data will be made available upon reasonable request to corresponding author.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2024.102692>.

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