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Development and psychometric validation of a novel measure of sensory expectancies associated with E-cigarette use

Meghan E. Morean[a,b,*], **Suchitra Krishnan-Sarin**[b], **Steve Sussman**[c], **Jonathan Foulds**[d], **Howard Fishbein**[e], **Rachel Grana**[f], **Bonnie Halpern-Felsher**[g], **Hyoshin Kim**[h], **Scott R. Weaver**[i], and **Stephanie S. O'Malley**[b]

[a]Department of Psychology, Oberlin College, 120 W. Lorain St., Oberlin, OH 44074, USA

[b]Department of Psychiatry, Yale School of Medicine, 34 Park St. New Haven, CT 06519, USA

[c]Institute for Health Promotion & Disease Prevention Research, University of Southern California, 2001 N Soto Street, 3rd Floor, MC 9239, Los Angeles, CA 90032, USA

[d]Penn State Tobacco Center of Regulatory Science, Penn State University, College of Medicine, 500 University Drive, P.O. Box 850, Hershey, PA 17033, USA

[e]Health Sector, Westat, 1450 Research Boulevard, TC3030, Rockville, MD 20850, USA

[f]Tobacco Control Research Branch, Behavioral Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute, 9609 Medical Center Drive, Rockville, MD 20850, USA

[g]Division of Adolescent Medicine, Stanford Medicine, 770 Welch Rd Suite 100, Stanford, CA 94304, USA

[h]Battelle Public Health Center for Tobacco Research, 550 King Ave., Columbus, OH 43201, USA

[i]School of Public Health, Georgia State University, 878 Urban Life Building, 140 Decatur, St. Atlanta, GA 30303, USA

Abstract

Introduction: E-cigarette dependence measures largely focus on e-cigarette use ("vaping") that is linked to nicotine use, and measures assessing sensory aspects of vaping that may influence use (e.g., taste) are limited in scope. Thus, we developed the novel Sensory E-cigarette Expectancies Scale (SEES).

Methods: In Summer 2017, 610 adult e-cigarette users (48.7% male, 84.9% White, 37.41[± 12.15] years old) completed an online survey that included 23 SEES items. Psychometric

*Corresponding author at: Department of Psychology, Oberlin College, 120 W. Lorain St., Oberlin, OH 44074, USA., Meghan.Morean@oberlin.edu (M.E. Morean).

Contributors
Drs. Morean, Krishnan-Sarin, Sussman, Foulds, Fishbein, Halpern-Felsher, Kim, Weaver, and O'Malley conceptualized the study and developed study hypotheses. Drs. Morean, Krishnan-Sarin, and O'Malley developed and implemented the self-report survey. Dr. Morean ran the statistical analyses and wrote the first draft of the manuscript. Drs. Krishnan-Sarin, Sussman, Foulds, Fishbein, Halpern-Felsher, Kim, Weaver, and O'Malley provided feedback on multiple versions of the manuscript. All authors approved the final version of the manuscript.

Conflict of interest
No conflicts declared in relation to the current study.

analyses included evaluating latent structure, internal consistency, measurement invariance, mean differences, and test-criterion relationships.

Results: Factor analyses supported a 9-item, 3-subscale structure (taste/smell, pleasure/satisfaction, vapor cloud production). Subscales evidenced internal consistency and scalar invariance by sex, race, smoking status (current/not), vaping status (daily/not), e-liquid nicotine content (yes/no), and device type (cig-a-likes/vape-pens/Advanced Personal Vaporizers [APVs]/Mods). Women and daily e-cigarette users reported stronger SEEs for taste/smell and pleasure than their counterparts. Non-white participants reported stronger SEEs for cloud production than White participants. Cig-a-like users reported the weakest SEEs for taste/smell and weaker SEEs linked to cloud production than APV/mod users. SEES scores evidenced convergence with nicotine dependence (mean r = .36). Finally, SEES scores predicted vaping frequency and habitual vaping concurrently and incrementally beyond nicotine dependence.

Conclusions: The SEES evidenced good psychometric properties, suggesting that the measure can be used to assess sensory vaping expectancies in adults. Importantly, SEES scores indicated that sensory expectancies are related, yet distinct, from nicotine dependence. Future research should evaluate how SEEs relate to product characteristic preferences and patterns of vaping including the development and maintenance of addiction.

Keywords

Electronic cigarettes; E-cigarettes; Vaping; Dependence; Expectancies; Expectancy

1. Introduction

While tobacco cigarettes continue to be the most commonly used tobacco product by American adults (e.g., Hu, 2016), the use of e-cigarettes (also referred to as electronic nicotine delivery systems [ENDS]) has increased in recent years (e.g., King, Patel, Nguyen & Dube, 2014). Currently, most adult e-cigarette users "vape" e-liquids that contain nicotine, although rates differ by cigarette smoking status (e.g., daily smokers: 83.8%; former smokers: 73.4%; never smokers36.9%; Weaver, Kemp, Heath, Pechacek & Eriken, 2017). Importantly, there is evidence that vaping nicotine e-liquids can produce comparable peak nicotine levels to smoking tobacco cigarettes (Marsot & Simon 2016). Given that nicotine serves as a primary reinforcer (Benowitz, 2010), recent research has focused on assessing e-cigarette dependence that is linked to nicotine addiction, similar to how dependence traditionally has been assessed for tobacco cigarettes (e.g., Etter & Eissenberg, 2015; Foulds et al., 2014; Liu, Wasserman, Kong, & Founds, 2017; Morean et al., 2018a,b). However, not all e-cigarette users report vaping e-liquid containing nicotine (e.g., Weaver et al., 2017), which provides preliminary evidence that at least some e-cigarette use may be driven by factors other than nicotine dependence.

One psychosocial construct that may be contributing to e-cigarette use is outcome expectancies, or the effects that individuals anticipate experiencing as a result of using a substance. A vast literature suggests that expectancies are predictors of the initiation, maintenance, and cessation of a wide range of substances (e.g., [stimulants] Aarons et al., 2001; [cigarettes] Brandon & Baker, 1991; [alcohol] Brown et al., 1987; [cannabis] Connor et al., 2011; [e-cigarettes] Harrell et al., 2014). Of central relevance to the current study, previous research on cigarette smoking has highlighted the importance of expectancies for “pleasurable sensorimotor sensations” that drive cigarette smoking but are distinct from nicotine dependence (e.g., “I enjoy the sensations of a long, slow exhalation of smoke;” Tucker, Shadel, Edelen, Stucky, Hansen, & Cai, 2014). In the case of tobacco cigarette smoking, many of these sensations (e.g., throat hit) are thought to become reinforcing overtime because they have consistently been paired with nicotine delivery (Rupprecht et al., 2015).

While cigarette smoking and vaping may share some similar sensory experiences (e.g., throat hit), e-cigarettes likely produce an even broader range of sensory experiences that may promote use. For example, the broad category of ENDS that colloquially are referred to as “e-cigarettes” comprises products that, among many other features, come in a variety of shapes and sizes, may be disposable or rechargeable, allow users to vape e-liquids containing varying nicotine concentrations (0 mg/ml to 60 mg/ml), allow users to customize features that influence e-liquid delivery and vapor cloud production (e.g., voltage, resistance), and provide users with a plethora of e-liquid flavors that are prohibited in traditional cigarettes in many countries (e.g., fruit, candies/desserts, sodas, energy drinks; Barrington-Trimis et al., 2017; E-cigarette Academy, 2017; Kim, Davis, Dohack & Clark, 2017). Given the many unique features of e-cigarettes, it is likely that e-cigarette use is influenced, in part, by sensory factors that may promote use but that are distinct from nicotine dependence. To this end, recent research has begun to examine pleasurable sensory vaping expectancies. For example, Harrell et al. (2014) found that former smokers expected e-cigarettes to taste better than traditional cigarettes. Further, Pokhrel et al. (2014) found that three positive sensory expectancies (i.e., smell good; feel good taste; have good breath) are associated with intentions to vape, lifetime vaping, and past 30-day vaping. Extending this work, Morean and L’Insalata (2017) found that holding stronger expectancies for positive reinforcement from vaping (comprising items “E-cigarettes taste good; I enjoy the taste sensations while vaping; When I vape the taste is pleasant; I will enjoy the flavor of an e-cigarette; and I will enjoy feeling an e-cigarette on my tongue and lips”) is associated with increased vaping frequency and stronger e-cigarette nicotine dependence. Although these early findings are encouraging, the range of sensory expectancies assessed in each of the exemplar studies was limited. Thus, the field would benefit from the addition of a more comprehensive measure of sensory vaping expectancies that would help researchers better understand the full range of sensory experiences that influence e-cigarette use. Of note, such a measure may be especially useful when included alongside e-cigarette nicotine dependence measures. Therefore, in the current study, we developed a novel measure of sensory expectancies associated with vaping – The Sensory E-cigarette Expectancies Scale [SEES] – and evaluated its psychometric properties (see the Data Analytic Plan for details on all psychometric analyses).

2. Methods

2.1. The SEES: item set development

We developed an initial item pool that comprised 23 SEE items that were obtained from several sources. First, a group of 14 subject matter experts (SMEs; researchers who had published extensively in the field of e-cigarette use and/or e-cigarette dependence) reviewed the Patient-Reported Outcomes Measurement Information System (PROMIS) Emotional and Sensory Expectancy Item Banks (Tucker et al., 2014), which were developed to assess cigarette smoking expectancies. The SMEs identified 6 items that could be directly or nearly directly adapted for use with e-cigarettes. Second, the SMEs developed 17 novel SEE items that they felt represented important and unique sensory expectancies associated with vaping. The instructions, formatting, and response scale for the SEES were modeled after the PROMIS-E (Morean et al., 2018b), a psychometrically sound version of the PROMIS Nicotine Dependence Item Banks (Shadel, Tucker, Edelen, Stucky, Handen, & Cai, 2014) that was adapted for use with e-cigarettes.

2.2. Psychometric evaluation

2.2.1. Participants—610 adults who reported vaping at least weekly completed a 20-min, online survey in Summer 2017 (51.3% female, 84.9% White, mean age37.41[± 12.15] years, 36.9% daily cigarette smokers, 57.5% daily e-cigarette users).

2.2.2. Procedures—The Institutional Review Board of “blinded university” deemed the current study to be exempt from review due to the low risk and anonymous nature of the study. Participants were recruited through Qualtrics Online Sample, a secure, market research service operated by Qualtrics, Inc. Qualtrics sent emails to participants who they deemed as likely to be eligible for our study based on their responses to the demographics survey that they completed when they first volunteered to be Qualtrics “panelists” (e.g., lifetime cigarette smoking status). Interested individuals clicked on the email link, which directed them to the study eligibility questions. Eligible individuals provided consent prior to participating. Qualtrics directly compensated participants based on the terms of their pre-established agreements (not to exceed $10). Although the exact amount that each participant is compensated is not made available, Qualtrics states that participants “receive an incentive based on the length of the survey, their specific panelist profile, and target acquisition difficulty. The specific types of rewards vary and may include cash, airline miles, gift cards, redeemable points, sweepstakes entrance, and vouchers” (European Society for Opinion and Market Research, 2014).

2.2.3. Measures

Demographics.: Participants reported on their sex, race, and age.

E-cigarette Use.: As part of the eligibility screening process, participants were asked “On average, how often do you use electronic cigarettes (also known as vaping)?” To be eligible for this study, participants had to report vaping at least once a week (response options: never, 1–2 times per year, 3–11 times per year, once a month, 2–3 times a month, once a week or more). Participants subsequently reported on two indices of vaping frequency: days per week (i.e., “On average, how many days per week do you vape?” Response options: 1–7 days per week) and times per day (“On days when you vape, how many times do you typically vape?” Response options: 1–4, 5–9, 10–14, 15–19, 20–29, 30 or more). Daily use was defined as having vaped 7 days per week; all other scores were categorized as non-daily vaping.

E-liquid Nicotine Content.: Participants reported whether “[they] usually use e-liquids that contain nicotine” (response options: no/yes).

E-cigarette Device Type/Model.: Participants were provided with four pictures of common e-cigarette models: a cig-a-like; a second-generation, mid-size, vape-pen; an advanced personal vaporizer (APV); and a fourth-generation box mod (see Fig. 1). They then reported “which type of e-cigarette looks most similar to the one that [they] typically use.”

Self-Report Habit Index for E-cigarettes.: Using a 5-point rating scale ranging from “strongly disagree” to “strongly agree,” participants responded to six items that previously were validated for assessing habitual e-cigarette use (Morean et al., 2018c). The SRHI-E represents an abbreviated version of the 12-item SRHI, which was validated for assessing engagement in non-substance related behaviors like using public transportation, watching tv, eating candy, and turning on music at home (Verplanken & Orbell, 2003). Example SRHI-E items include “Vaping is something I do automatically” and “Vaping is something I would find hard not to do.” Internal consistency in the current sample was excellent (Cronbach’s α = 0.91).

E-cigarette Dependence.: Two measures were used to assess e-cigarette dependence.

Participants completed the Penn State E-Cigarette Dependence Index (PSECDI; Foulds et al., 2014), which comprises ten items that were adapted from cigarette dependence measures and was normed on a large sample of e-cigarette users. The PSECDI contains continuous and categorical/binary items, making it impossible to calculate internal consistency using traditional methods. However, as a proxy, we calculated the Guttman’s Lambda value associated with the 6 binary items, which indicated good internal consistency (0.83). Participants also completed the PROMIS-E (Morean et al., 2018b), which is a psycho-metrically sound measure of e-cigarette nicotine dependence. To complete the PROMIS-E, participants used a 5-point rating scale ranging from “never” to “almost always” to rate their experiences of 22 symptoms of nicotine dependence associated with e-cigarette use. Example items include: “When I go without vaping for a few hours, I experience craving” and “I find myself reaching for e-cigarettes without thinking about it.” Internal consistency was excellent in the current sample (α = 0.98).

Cigarette Use.: Participants reported on their current cigarette smoking status (“I have never been a cigarette smoker; I am a former smoker, meaning that I used to smoke cigarettes, but I successfully quit; I smoke cigarettes occasionally - at least once a month; and I smoke cigarettes daily”). For the invariance analyses and evaluations of mean-level differences, a variable reflecting current cigarette smoking (no/yes) was created.

2.3. Data analytic plan

2.3.1. Descriptive statistics—Descriptive statistics were run to ensure that categorical variables had adequate cell sizes and that continuous variables approximated normality.

2.3.2. Latent structure—Using Mplus 7.0, we ran an exploratory factor analysis (EFA) of the SEE items within a randomly selected 50% of the total sample (n = 310). Given that a latent factor generally should comprise at least three items to be estimated reliably (Jöreskog & Sörbom, 1989), we considered solutions ranging from 1 to 7 factors. Plausible latent structures were determined based on a combination of eigenvalues (> 1)/scree plots; model fit; the magnitudes of item loadings (i.e., factor loadings ≥0.70 with cross-loadings < 0.30), the number of items per factor, and the interpretability of the factors (e.g., Tabachnick and Fidell, 2013). Plausible latent structure(s) identified via EFA were fit to the remaining 50% of the data (n = 310) using Confirmatory Factor Analysis (CFA). For all factor analytic models, we specified robust maximum likelihood estimation. Missing data (< 1%) were handled using Full Information Maximum Likelihood. As is recommended (Jackson, Gillaspy, & Purc-Stephenson, 2009), acceptable model fit was determined based on a combination of fit indices following cutoffs: Bentler's Comparative Fit Index (CFI) > 0.95, Root Mean Square Error of Approximation (RMSEA) < 0.08, and Standardized Root Mean Square Residual (SRMR) < 0.08 (Hu and Bentler, 1999).

2.3.3. Internal consistency—For each latent factor, Raykov's Rho (ρ) was calculated as an index of internal consistency (Raykov, 1997).

2.3.4. Measurement invariance—Multi-group CFA was used to evaluate measurement invariance (MI) of the SEES. Specifically, MI was used to establish whether the latent structure confirmed via CFA fit the data for subgroups of interest comparably enough to permit interpretable mean-level comparisons. In the current study, MI was evaluated for sex, race (White/Non-White), cigarette smoking status (no/yes), vaping status (non-daily/daily), e-liquid nicotine content (no/yes), and e-cigarette device type (cig-a-like, second-generation mid-size vape-pen, advanced personal vaporizer, fourth-generation mod). Three levels of invariance must be established for mean-level comparisons to be interpretable: configural invariance(i.e., the same number of latent factors comprising the same items are confirmed for both groups), metric invariance (i.e., the magnitude of the item factor loadings are comparable between groups), and scalar invariance (i.e., the magnitude of the item factor loadings and their intercepts [or origins] are comparable between groups; Chen, 2008; Steenkamp & Baumgartner, 1998; Widaman & Reise, 1997). If all items loaded significantly onto their specified factor(s) and the model fit the data, configural variance was established. If the change in model fit from the configurally invariant model to the model evaluating metric invariance did not exceed RMSEA ≥0.015, CFI ≥ 0.01, or SRMR ≥0.030, metric invariance was achieved, and scalar invariance was achieved if changes in model fit from the model testing metric invariance did not exceed CFI ≥ 0.010 accompanied by a change in SRMR ≥0.010 or RMSEA ≥0.015 (Chen, 2007). Note that we did not consider the chi-square statistic because it is dependent on sample size, making it a poor choice for evaluating fit in samples larger than 200 (Chen, 2007).

2.3.5. Comparison of factor scores and mean subscale scores—We anticipated that many researchers ultimately will conduct analyses using the SEES subscale scores in a manifest rather than latent variable framework. Using a summary scale approach (or, preferably a subscale mean approach) to scoring assumes that all items have equal factor loadings. However, CFA shows that the magnitudes of the items' factor loadings vary, such that the latent factor is more strongly related to some items than others. To determine whether using a mean score approach was supported, we conducted bivariate correlations between the latent factor scores derived from CFA and the mean scores for each subscale.

2.3.6. Mean-level comparisons—For all subgroups for which scalar MI was established, between-groups comparisons were made using independent-samples *t*-tests or ANOVA.

2.3.7. Convergence with dependence—Bivariate correlations were used to examine the unadjusted relationships between the SEES and the two indices of e-cigarette dependence (i.e., the PSECDI and the PROMIS-E).

2.3.8. Test-criterion relationships—To provide evidence of the concurrent validity of the SEES, univariate general linear models (GLMs) were run to evaluate the extent to which the SEES was associated with vaping frequency (i.e., days/week, times/day) and habitual e-cigarette use after accounting for demographic covariates (i.e., sex, age, race, e-liquid nicotine content). To evaluate the incremental validity of the SEES, all GLM models were rerun with the PSECDI and the PROMIS-E included as independent variables to determine whether the SEES scores accounted for significant variance in the e-cigarette outcomes above and beyond nicotine dependence. Note that the first item of the PSECDI, which assesses use frequency of e-cigarette use, was omitted from the total PSECDI scores for the models predicting e-cigarette use frequency.

3. Results

3.1. Descriptive statistics

The distributions of all continuous variables approximated normality and the cell sizes for all categorical variables were adequate (Table 1). The fact that the distribution of each of the SEES item scores approximated normality and that the response scale for the SEES comprised five choices supported our decision to treat the SEES items as continuous (Rhemtulla, Brosseau-Liard & Savalei, 2012).

In sum, participants reported vaping an average of 5.6 (1.9) days per week and an average corresponding to the answer choice of "10–14 times per day on days when they used e-cigarettes" (i.e., 3.03[1.88]). Overall, participants reported a moderate level of e-cigarette dependence on the PSECDI (10.36[4.57]), a relatively low level of e-cigarette dependence on the (PROMIS-E: 1.84[1.05]), and moderate habitual e-cigarette use (SRHI-E: 3.32[1.00]). Most participants reported using nicotine e-liquid (78.5%), similar to results observed in a national sample (Weaver et al., 2017). Participants reported using cig-a-likes(20.5%), mid-size e-cigarettes/vape-pens (31.1%), APVs (20.7%), and mods (27.7%).

3.2. Latent structure

Examination of eigenvalues > 1 and the associated scree plots suggested that the 1-, 2-, and 3-factor solutions should be investigated further. None of the three models in which all 23 SEES items were included fit the data well, suggesting that items needed to be removed to improve fit. We retained items with factor loadings ≥0.70 and cross loadings < 0.30 to ensure that the primary latent factor accounted for sizeable variance in each item (≥49%) and that minimal variance in each item (< 10%) was accounted for secondary factor(s). After eliminating items with insufficient loadings, only two potentially viable latent structures remained: the 1- and 3-factor models; the second factor from the two-factor model did not contain any items with loadings ≥0.70 (See Table 2). The single-factor model comprised 13 items. The 3-factor model comprised 9 items (3 items per factor). The 1-factor and 3-factor models were interpretable, with latent factors reflecting general sensory expectancies (1-factor) and enjoyment of taste/smell of vaping, experiencing pleasure from vaping, and producing vapor clouds (3-factor). As such, the 1- and 3-factor models were fit to the second random sample using CFA.

The 1-factor model did not fit the data (RMSEA = 0.090, CFI = 0.922, SRMR = 0.046). However, the 3-factor model fit the data well (RMSEA = 0.66, CFI = 0.979, SRMR = 0.26), with all items loading onto their respective factors at ≥0.70 (Table 2). Correlations among the three subscales indicated that they were related yet sufficiently distinct (Taste/Smell with Pleasure: $r = 0.56$, Taste/Smell with Clouds: r = 0.49, Pleasure with Clouds: r = 0.52, *p*-values < .001). As such, further analyses were conducted using the 3-factor model.

3.3. Internal consistency

Each factor was internally consistent (taste/smell $\rho = 0.88$, pleasure $\rho = 0.90$, vapor clouds $\rho = 0.85$).

3.4. Measurement invariance

Based on the cutoffs described in the methods section, the SEES scores were scalar invariant for all subgroups evaluated (See Table 3).

3.5. Comparison of factor scores and mean subscale scores

Correlations between corresponding SEES subscale scores derived using MPLUS factor scores and using a mean scoring approach ranged from 0.97 to 0.99, suggesting that treating the subscales as manifest variables was justifiable.

3.6. Mean-level comparisons

An adjusted alpha level of 0.01 was used as the threshold for statistical significance for the independent-samples *t*-tests (Table 4). Women and daily e-cigarette users reported stronger SEESs for pleasure and taste/smell than their counterparts. Non-White individuals reported stronger cloud scores than White individuals.

ANOVA results showed that SEES scores differed significantly by type of e-cigarette device typically used for taste/smell (F [3606] = 11.92, p < .001) and cloud production (F[3606] = 5.42, p < .001). Bonferroni-corrected post-hoc comparisons revealed that users of second-generation, mid-size devices (M = 3.03 [0.84]), APVs (M = 3.24 [0.70]) and mods (M = 3.17 [0.78]) reported significantly stronger SEESs for taste/smell than cig-a-like users (M = 2.67 [0.99]), p-values < .001. Furthermore, APV (*M* = 2.44 [1.19]) and mod users (*M* = 2.40 [1.15]) reported stronger SEESs for cloud production than cig-a-like users (M = 1.92 [1.23]), p-values = .003. No other significant differences were observed.

3.7. Convergence with dependence

The SEES subscales correlated modestly to moderately with the PSECDI (Smell/Taste $r = 0.32$; Pleasure $r = 0.42$, Clouds $r = 0.19$) and the PROMIS-E (Smell/Taste $r = 0.33$; Pleasure $r = 0.47$, Clouds $r = 0.35$, p-values < .001)

3.8. Test-criterion relationships

Stronger Taste/Smell expectancies were associated with more frequent vaping (days/week; times/day) in the models evaluating both concurrent and incremental validity (See Table 5). Expecting stronger pleasurable sensations was associated with more frequent vaping (days/ week; times/day) in the models evaluating concurrent validity and with stronger habitual e-cigarette use in the concurrent and incremental models. Finally, expecting stronger enjoyment of vapor cloud production was associated with more frequent vaping (days/week; times/day) and stronger habitual e-cigarette use in the concurrent and incremental models.

4. Discussion

Evidence of strong psychometric properties suggests that the SEES has utility for assessing sensory expectancies associated vaping in adults. The SEES comprises three latent factors reflecting expectancies for taste/smell, pleasure/satisfaction, and vapor cloud production (unique among e-cigarette expectancy measures). Each subscale evidenced good internal consistency and scalar invariance by sex, race, cigarette smoking status, vaping status, e-liquid nicotine content, and device type.

The SEES was sensitive to several mean-level differences within the subgroups of interest. First, women reported stronger SEEs related to taste/smell and pleasure than did men, which is consistent with prior research on cigarette smoking suggesting that women may be more likely than men to smoke for sensory reasons like experiencing pleasure and enjoying the smell of smoke (e.g., Perkins, 1996; WHO, 2010). Second, daily e-cigarette users reported stronger SEEs for taste/smell and pleasure than did non-daily users, which may reflect their motivations for being daily users (i.e., if a user finds vaping more pleasurable and enjoys the taste, he/she should be more likely to vape daily). Third, cig-a-like users reported the weakest SEEs for taste/smell relative to users of all other devices and reported weaker SEESs for cloud production than APV/Mod users. These findings are consistent with the fact that cig-a-likes, unlike more sophisticated vaping devices (APVs/Mods), are characteristically unable to be altered in ways that increase vapor production and/or enhance flavor intensity (e.g., adjusting voltage, resistance; E-cigarette Academy, 2017). Given that differences in expectancies were found across product types, the results also suggest that it is important to consider e-cigarette device type when assessing vaping expectancies and their relations to vaping outcomes. Finally, non-White individuals reported stronger SEEs for cloud production than did White individuals. It is not immediately evident why this difference emerged, and future research is needed to explore potential differences in SEEs based on race.

The SEES also evidence convergent relationships with nicotine dependence. However, SEES subscale scores shared an average of approximately 13% of the variance with nicotine dependence, indicating that SEEs and nicotine dependence are related yet distinct constructs. Finally, the SEES evidenced test-criterion relationships with vaping frequency and habitual e-cigarette use, accounting for significant variance in each outcome above and beyond demographic characteristics and nicotine dependence. When considered in concert, the study findings suggest that sensory e-cigarette expectancies represent an important construct that is associated with vaping behavior above and beyond symptoms of nicotine dependence.

When interpreting the study findings, several limitations should be noted. First, data were self-reported and, therefore, were limited by participants' willingness to provide accurate responses. Second, data were collected online, so it was not possible to collect biomarkers to confirm e-cigarette or cigarette use. Third, when invariance analyses were run for smoking status, we dichotomized the data to reflect current smokers (all past-month smokers) versus non-current smokers (never smokers and former smokers). It is possible that never smokers may hold different SEEs than former or current smokers, but the sample size of never smokers was too small (n = 25) to justify treating never smokers as an independent sample during invariance testing. Therefore, future research is needed to evaluate whether SEEs of never smokers differ from those of former and current smokers. Fourth, nicotine e-liquid use was conceptualized in a simplistic fashion within the current study (no/yes), and it is possible that SEES scores may vary when a broader range of nicotine concentrations are assessed (i.e., 0 mg/ml–60 mg/ml). Finally, the sample comprised American adults who volunteered to be research participants through *Qualtrics Inc*. Additional research is needed to evaluate the psychometric properties of the SEES for use with more diverse populations (e.g., adolescents, nationally representative samples, international samples, adults seeking smoking cessation treatment).

Despite these limitations, the current study contributes a novel, more comprehensive measure of sensory e-cigarette expectancies to the field. Similar to previous research on tobacco cigarettes (e.g., Tucker et al., 2014) and e-cigarettes (Harrell et al., 2014; Morean & L'Insalata, 2017, Pokhrel et al., 2014), it appears that sensory aspects of vaping, which are distinct from nicotine dependence, contribute to e-cigarette use. However, researchers are encouraged to consider both nicotine dependence and sensory expectancies as important factors that influence vaping behavior, as, together, they accounted for between 5% and 28% of the variance in vaping outcomes. Future research is needed to evaluate whether the SEES is associated with preferences for specific product characteristics (e.g., the ability to alter resistance or voltage, the use of different e-liquid flavors and/or nicotine concentrations [e.g., Brown & Cheng, 2014]). In addition, research examining the extent to which the SEES is associated with the development and maintenance of e-cigarette use and dependence is warranted.

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Fig. 1.
Pictures of vaping devices presented to participants.

Table 1

Participant demographics.

	Percentage	
Sex (% male)	48.7	
Race (% White)	84.9	
Smoking status		
Never	8.2	
Former	31.0	
Occasional	23.9	
Daiy	36.9	
Current smoking status (% yes)	60.8	
Daily vaping status (% yes)	57.5	
E-liquid nicotine use (% yes)	78.5	
Device Type		
Cig-a-like	20.5	
Vape-pen	31.1	
Advanced Personal Vaporizer	20.7	
Box Mod	27.7	
	Mean (Std. Dev)	Range
Age	37.71 (13.15)	18–77
Vaping frequency		
Days/Week	5.56 (1.94)	1–7
Times/Day	13.06 (10.39)	0–30
Habitual Use (SRHI-E)	3.32 (1.00)	1–5
E-cigarette dependence		
Penn state	10.36 (4.57)	1–21
PROMIS-E	1.84 (1.05)	0–4
Smell/Taste	3.04 (0.85)	0–4
Pleasure	2.54 (1.04)	0–4
Clouds	2.27 (1.19)	0–4

The response scale for vaping frequency (times per day) originally was presented to participants in ranges (e.g., 5–9). To facilitate interpretation of the data in the table, the ranges were converted to means (e.g., 5–9 times per day was recoded as 7 times per day). However, the original scaling of the variables was used for all other data analyses.

Table 2

Model fit and item factor loadings associated with the exploratory and confirmatory factor analytic models.

	Sensory dependence items	Exploratory factor analysis						Confirmatory factor analysis		
		One-Factor	**Two-Factor**		**Three-Factor**			**Three-Factor**		
		RMSEA .126 / CFI .748 / SRMR .081	**RMSEA .102**	**CFI .831 / SRMR .059**	**RMSEA .088**	**CFI .921**	**SRMR .033**	**RMSEA .066**	**CFI .979**	**SRMR .026**
		Sensory dependence	**Taste/Smell**	**Sensation**	**Taste/Smell**	**Pleasure**	**Clouds**	**Taste/Smell**	**Pleasure**	**Clouds**
1	I like the feeling of vaping.	**0.800**	0.550	0.364	0.455	0.449	0.081			
2	I like the smell of the vapor.	0.600	**0.867**	−0.094	**0.770**	−0.111	0.144	**0.795**		
3	I like the taste of vaping.	0.653	**0.924**	−0.066	**0.836**	0.048	−0.027	**0.898**		
4	I like the feeling of creating vapor clouds.	**0.764**	0.295	0.501	0.231	0.069	**0.787**			**0.889**
5	I like how creating vapor clouds looks visually appealing/cool.	**0.715**	0.139	0.582	0.061	0.010	**0.868**			**0.818**
6	I like the flavor of vapor.	0.642	**0.888**	−0.074	**0.846**	0.045	−0.046	**0.843**		
7	I like the sensations of a long, slow exhalation of vapor.	**0.805**	0.298	0.513	0.254	0.500	0.221			
8	I like how vaping makes me feel good physically.	**0.771**	0.145	0.682	0.023	**0.745**	0.186		**0.755**	
9	I like the feel of inhaling vapor into my mouth.	**0.824**	0.253	0.662	0.248	0.640	0.098			
10	I like the feeling of satisfaction that I get from vaping.	**0.814**	0.322	0.587	0.246	**0.777**	−0.051		**0.922**	
11	I like the feeling of pleasure that I get from vaping.	**0.802**	0.301	0.587	0.172	**0.796**	−0.015		**0.920**	
12	I like that vaping gives me something to do with my hands.	0.643	0.214	0.407	0.148	0.452	0.167			
13	I like the way my e-cigarette feels on my lips or tongue.	**0.744**	0.152	0.661	0.050	0.608	0.319			
14	I like watching the vapor as I exhale it.	**0.768**	0.212	0.580	0.127	0.209	0.631			
15	I like vaping because it feels good.	**0.836**	0.243	0.655	0.175	0.675	0.150			
16	I like doing vape tricks (e.g., blowing vapor clouds or shapes like rings).	0.577	0.077	0.596	0.044	−0.100	**0.825**			**0.709**
17	I like the smell of e-liquid.	0.600	0.623	0.044	0.599	−0.094	0.292			
18	I like the sensation I feel in my throat when I vape.	**0.780**	0.218	0.605	0.176	0.496	0.257			
19	I like the buzz I get from vaping.	0.632	0.007	0.571	0.099	0.393	0.469			

	Sensory dependence items	Exploratory factor analysis									Confirmatory factor analysis		
		One-Factor			Two-Factor			Three-Factor			Three-Factor		
		RMSEA	CFI	SRMR	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR
		.126	**.748**	**.081**	**.102**	**.831**	**.059**	**.088**	**.921**	**.033**	**.066**	**.979**	**.026**
		Sensory dependence			**Taste/Smell**	**Sensation**		**Taste/Smell**	**Pleasure**	**Clouds**	**Taste/Smell**	**Pleasure**	**Clouds**
20	I like how my vaping device looks.		0.608		0.382	0.314		0.191	0.050	0.535			
21	I like tinkering with all the features of my vaping device.		0.614		0.216	0.372		0.126	0.025	0.639			
22	I like the sensation of exhaling vapor.		**0.851**		0.304	0.606		0.279	0.398	0.359			
23	I like the “throat hit” I get from vaping.		0.686		0.117	0.523		0.086	0.521	0.195			

Acceptable model fit determined by RMSEA (Root Mean Square Error of Approximation) < 0.08, CFI (Bentler’s Comparative Fit Index) > 0.95, and SRMR (Standardized Root Square Mean Residual) < 0.08. Bolded factor loadings indicate items that were retained based on having primary factor loadings ≥0.70 and cross-loadings < 0.30.

Table 3

Measurement invariance of the SEES for subgroups of interest.

Level of invariance	**Sex**			**Race**			**Cigarette smoking status**		
	RMSEA	**CFI**	**SRMR**	**RMSEA**	**CFI**	**SRMR**	**RMSEA**	**CFI**	**SRMR**
Configural	0.063	0.975	0.040	0.068	0.971	0.043	0.061	0.980	0.040
Metric	0.056	0.977	0.043	0.071	0.965	0.053	0.053	0.983	0.043
Scalar	0.055	0.976	0.044	0.066	0.966	0.075	0.057	0.977	0.046
Level of invariance	E-cigarette use status			E-liquid. nicotine content			Device type		
	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR	RMSEA	CFI	SRMR
Configural	0.050	0.986	0.034	0.070	0.973	0.034	0.060	0.981	0.052
Metric	0.046	0.986	0.043	0.063	0.975	0.038	0.052	0.982	0.071
Scalar	0.067	0.977	0.052	0.075	0.970	0.047	0.059	0.972	0.076

Abbreviations are RMSEA (Root Mean Square Error of Approximation), CFI (Bentler's Comparative Fit Index), SRMR (Standardized Root Square Mean Residual). Sex (men:women), Race (White:non-White), Cigarette Smoking Status (not current:current), E-cigarette Use Status (non-daily:daily), E-liquid Nicotine Content (no:yes), Device Type (cig-a-like: second generation vape-pens: advanced personal vaporizers: mods). Scalar invariance was achieved in each case.

Table 4

Independent-samples *t*-tests comparing SEES scores within subgroups of interest.

	Sex		
Sub scales	Women (n = 313)	Men (n = 297)	*t*
Smell/Taste	3.14 (0.88)	2.92 (0.80)	3.25**
Pleasure	2.64 (1.08)	2.44 (0.98)	2.32**
Clouds	2.22 (1.26)	2.31 (1.11)	−0.88
	Race		
Sub scales	Non-White (n = 92)	White (n = 518)	*t*
Smell/Taste	3.18 (0.75)	3.01 (0.87)	1.78
Pleasure	2.72 (1.00)	2.51 (1.04)	1.83
Clouds	2.61 (1.15)	2.21 (1.19)	2.99**
	Cigarette smoking status		
Sub scales	Non-Current (n = 385)	Current (n = 225)	*t*
Smell/Taste	3.09 (0.81)	2.94 (0.91)	2.09
Pleasure	2.52 (1.02)	2.59 (1.07)	−0.83
Clouds	2.29 (1.14)	2.23 (1.26)	0.56
	E-cigarette use status		
Sub scales	Non-Daily (n = 259)	Daily (n = 351)	*t*
Smell/Taste	2.87 (0.95)	3.16 (0.75)	−3.99***
Pleasure	2.41 (1.06)	2.64 (1.00)	−2.81**
Clouds	2.35 (1.20)	2.21 (1.18)	1.43
	E-liquid nicotine content		
Sub scales	No (n = 111)	Yes (n = 479)	*t*
Smell/Taste	2.86 (0.98)	3.09 (0.79)	−2.29
Pleasure	2.36 (1.17)	2.56 (0.99)	2.09
Clouds	2.35 (1.22)	2.24 (1.18)	0.86

** $p < .010$,

*** $p < .001$.

All values are presented as mean (standard deviation).

Table 5

Evidence for concurrent and incremental relationships between the SEES sub-scales and e-cigarette use outcomes.

Independent variables	**Concurrent relationships**					
	Vaping frequency (Days/Week)		**Vaping frequency (Times/Day)**		**Habitual E-cigarette use**	
	F	η_P^2	**F**	η_P^2	**F**	η_P^2
Sex (Women)	0.02	.00	0.62	.00	9.79	.02**
Age	11.11	.02**	6.64	.01*	3.40	.01
Race (Non-White)	8.45	.01	0.82	.00	1.14	.00
Smoking Status (Current)	43.30	.07***	24.92	.04***	0.41	.00
Device Type (Cig-a-Like)	10.22	.05***	12.89	.06***	0.98	.01
Nicotine E-liquid Use (yes)	8.72	.02**	15.30	.03***	9.27	.02**
Taste/Smell	6.26	.01*	19.91	.04***	1.72	.00
Pleasurable Sensations	11.53	.02***	6.11	.01*	116.66	.17***
Vapor Cloud Production	5.32	.01*	9.68	.02**	13.47	.02***

	Incremental Relationships						
Sex (Women)	1.55	.00	0.12	.00	6.71	.01**	.02**
Age	5.35	.01*	1.69	.00	0.61	.00	.00
Race (Non-White)	5.41	.01	0.02	.00	0.14	.00	.00
Smoking status (Current)	51.39	.08***	40.72	.07***	0.48	.00	.01
Device type (Cig-a-Like)	11.86	.06***	13.59	.07***	0.57	.00	.00
Nicotine E-liquid use (yes)	5.45	.01*	8.74	.02**	0.08	.00	.00
Perm state dependence	1.94	.00	7.16	.01**	23.76	.04**	
PROMIS-E dependence	11.79	.02**	18.06	.03***	136.37	.19***	.44***
Taste/Smell	6.19	.01*	22.18	.04***	1.60	.00	.00
Pleasurable sensations	0.70	.00	0.89	.00	21.37	.04***	.05***
Vapor cloud production	9.70	.02**	19.32	.03***	4.85	.01*	.02*

Reference groups are listed in parentheses.

* $p < .05$,

** $p < .01$,

*** $p < .001$.